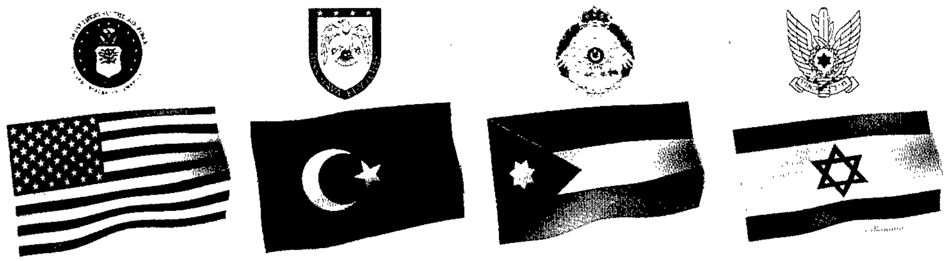


הציפורים הנודדות אינן יודעות גבולות

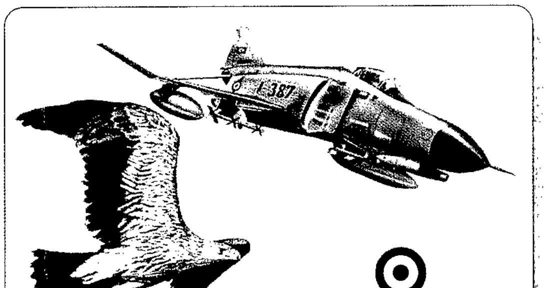
Migrating Birds Know No Boundaries

الطيور المهاجره لا تعترف بالحدود

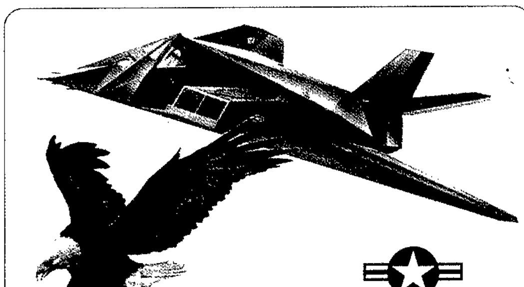
Tel Aviv University

The Society for the Protection of Nature in Israel

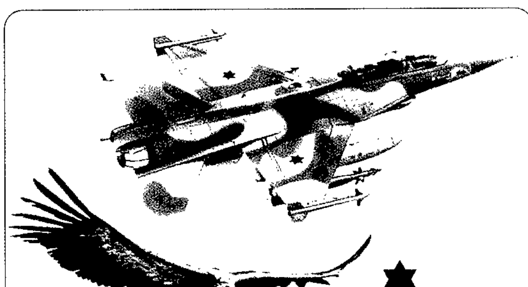
International Seminar on Birds and Flight Safety in the Middle East
Israel, April 25-29, 1999



F-4, Imperial Eagle, Turkey



F-117, Bald Eagle, USA



F-16, Griffon Vulture, Israel

F-16, Lanner Falcon, Jordan

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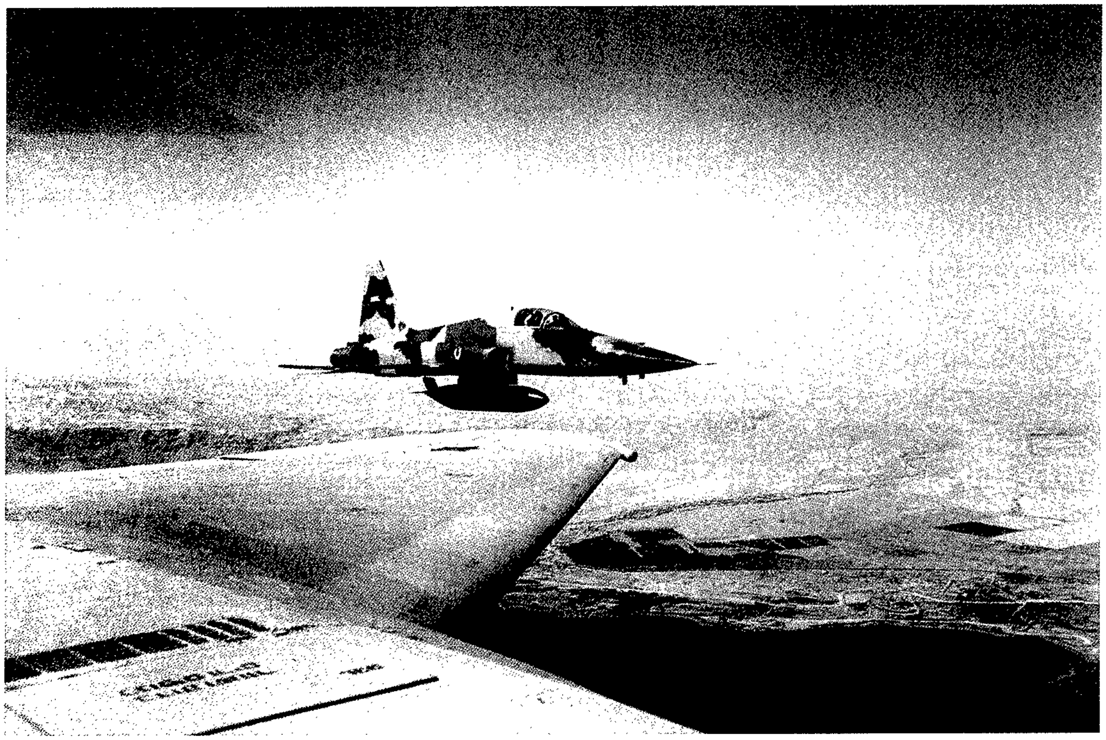
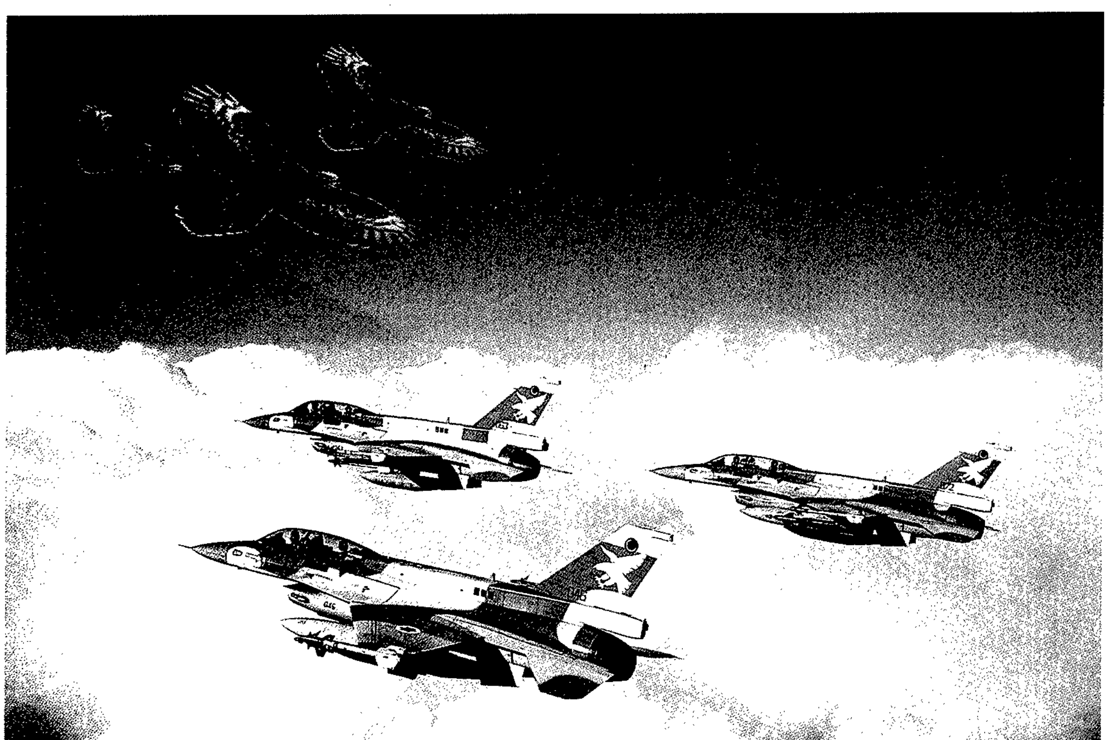


Above: A Royal Jordanian Air Force F-5 flying with in formation with an Israel Air Force F-15 over the Israel-Jordan border above the Dead Sea, as a tribute to cooperation and the peace process in the region. **Below:** TAKE CARE WE SHARE THE AIR. Three Israel Air Force F-16D with three honey buzzards. (Photo: Duby Tal, Albatross, Paul Doherty)



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ABSTRACT (Maximum 200 words)

This is an interdisciplinary conference. Topics include applying bird migration research to bird strike avoidance, development of NEXRAD-based Aircraft Hazard Advisory System, the US Bird Avoidance Model (BAM), birds and flight safety.

Table of Contents: Developing a real time warning system in the Middle East - from vision to reality; The Royal Netherlands Air Force: Two decades of bird strike prevention "En Route"; Bird flight forecast and information system; Next generation satellite-based technology for conservation and bird strike science; The Avian Hazard Advisory System; Three decades of tracking radar studies on bird migration in Europe and the Middle east; Review of 100 years of military; Aerodrome bird hazard prevention: case study at John F. Kennedy International Airport; The role and value of awareness programs in reducing bird hazards to aircraft; Conflict in the Royal Jordanian Air Force; Bird strikes and flight safety in the Turkey Air Force; Avifauna management policy of the Hellenic Air Force; United States Air Force Europe bird strike hazard reduction; Bird Remains Identification System (BRIS) - from a bi-national to a global database; From a local to regional ground survey network and its application in flight safety; Twenty-eight years of birdstrike damage in the Israel Air Force (IAF) 1972-1999; The United States Avoidance Model (BAM); Development of a GIS-based birds model migration model for the Middle East; A new technique for studying nocturnal bird migration; WSR-88D/98 Doperational capabilities and applications. Weather and biological targets; Factors affecting bird hazards in and around Israeli aerodromes; Factors affecting bird hazards in and around Israeli aerodromes; Pigeon and crow population control by trapping; Summary and action plan.

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Initiated by the International Center for the Study of Bird Migration, Latrun

Tel Aviv University — Israel Air Force — The Society for the Protection of Nature in Israel

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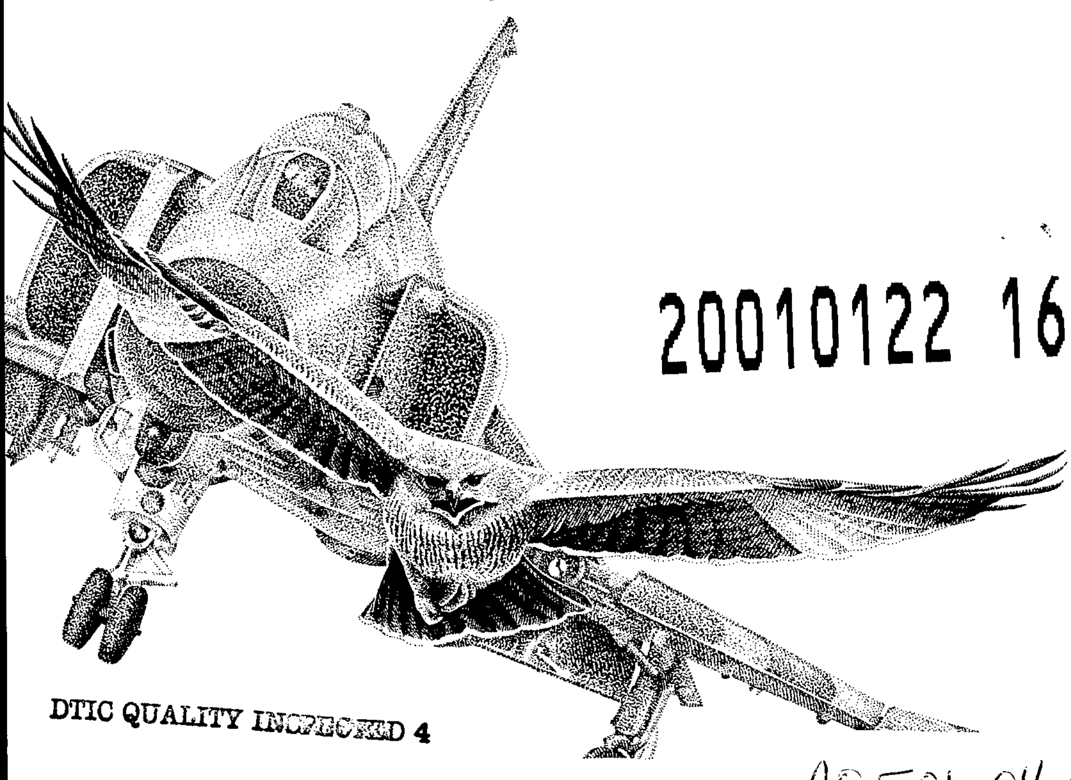

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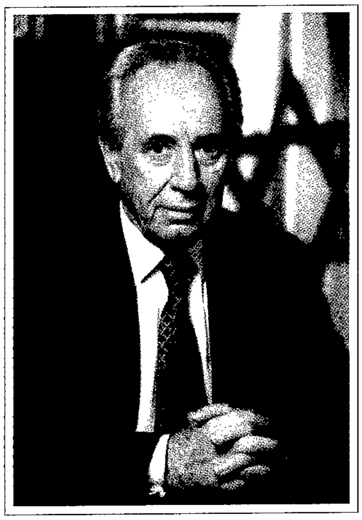


Coexistence Between Birds and Planes

If fish were in need of the governor's leave to swim
If birds were in need of government permits to fly
We would be left in a world without birds and without fish

Thus, freely translated, wrote Syrian poet Nizar Qabbani in one of his poems. A sea without fish? The sky without birds? Clearly, this would be terrible! A world without dimensions, without movement, without freedom? Fortunately, birds take to the skies without government permits. But planes fly by government and international license. What must we do, therefore, to prevent conflict between the free birds and the regulated airplanes?

The Israel Air Force, Tel Aviv University, and the Society for the Protection of Nature in Israel are trying to bring about an amicable relationship between the two. Certainly none of us would agree to a sky without birds, just as no one would accept a world without books. And we do need planes in our daily lives, for travel and defense.

I view this seminar, initiated by Yossi Leshem and dealing at the same time with both the freedom of birds and the safety of planes, as an important step in the creation of harmony in our changing world. Nature has always been multi-faceted. But when new elements are introduced, the need to create new harmony cannot be ignored.

That harmony is the subject of this book.

Shimon Peres
Minister for Regional Cooperation

"...וְכִתְּתוּ חַרְבוֹתָם לְאִתִּים וַחֲנִיתוֹתֵיהֶם לְמַזְמֵרוֹת..."
(ישעיהו ב' ד')

"...and they shall beat their swords into plowshares and their spears into pruning hooks" (Isaiah, 2;4).

"...فَيَطْبَعُونَ سُيُوفَهُمْ سِكَكًا وَرِمَاحَهُمْ مَنَاجِلَ..."

April 26, 1999, The International Seminar on Flight Safety in the Middle-East, at the Wall of Rememberence at Latrun: Five Officers salute to 4863 armour officers and soldiers who lost their lives since 1948 . Right to left: Colonel Malik Habashneh, Royal Jordanian Air Force; Brig. Gen. Mutat Bulgan, Turkish Air Force; Maj. General D. Athanassakos, Hellenic Air Force; Col. Roger C. Craig, United States Air Force; Maj. Gen. (Ret.) Haim Erez, Israeli Defence Force. (Photo: Yigal Pardo)

Dear Participants,

In 1983, Dr. Yossi Leshem initiated a joint research project with the Israel Air Force, the Society for the Protection of Nature, and Tel Aviv University with the objective of learning about the timing, altitudes, and pathways of migrating birds.
The Israel Air Force, whose skies were "reduced" after the peace treaty with Egypt, already suffered serious damage from collisions with birds. After the training zones were reduced, the risk of serious collisions with birds increased.
The Israel Air Force adopted the research results and began applying them in 1984. The research accurately mapped the pathways and timing of soaring bird migration and the application of this knowledge has lead to a significant decrease in the number of bird collisions with military aircraft.
The International Seminar on Birds and Flight Safety will expand our knowledge, with the intention of continuing to promote the issue and minimizing bird collisions with aircraft.

Major General Eitan Ben-Eliahu
Commander of the Israel Air Force

Distinguished Guests,

I would like to convey my best wishes and appreciation to the Israeli Air Force and all seminar participants.

We would like to express our gratitude to Maj. Gen. Eitan Bem-Eliahu, Dr. Yossi Leshem, Lockheed Martin and the Israel Air Force for making it possible for us to take part in this seminar. Improving flight safety standards at all levels has always been extremley important to the Royal Jordanian Air Force, and we believe that it is an essential investment, which saves life, money and equipment.

On behalf of the Royal Jordanian Air Force, I would like to thank you for your involvement and wish you all a safe year, free of bird collisions.

Best regards to all,

Major General Muhamad Kheir Ababneh
Chief of Air Staff, Royal Jordanian Air Force

Dear Commanders, Ladies and Gentlemen,

First, on behalf of the Turkish Air Force, I greet and welcome all the participants.
I would like to thank Maj. Gen. Ben-Eliahu, Israel Air Force Commander, Prof. Cohen, Rector of Tel-Aviv University, Dr. Shoshani, Chairman of the Board of the Society for the Protection of Nature in Israel, and all the persons who spent their precious time on the subject of "Birds and Flight Safety" highly related to the Air Traffic.
The seminar will be an important study to improve flight safety and reduce the risk of bird hazards to military aviation. The importance of this seminar will increase more and more as the subject is a commom problem of our countries, and in addition, the bonds existing between our nations will be strengthened as a result of the shared work and research, and its effects will be followed together with the peace process in the Middle East. I am sure and believe that the results of the seminar will be successful and will open the gate for new seminars in the near future.
Desiring the rise in the number of organizations of this type of seminar and study, I would like to thank you for your kind invitation, and take the opportunity to extend my most sincere wishes to all the participants.

General Ilhan Kilic
Commander, Turkish Air Force

Dear Seminar Participants,

Collisions between aircraft and birds are often ignored, sometimes anticipated, and then either accepted or avoided. It is impossible to fly without any risk, but once a risk is understood we start to weigh operational urgency against safety. Knowledge about the presence and behavior of birds will promote bird avoidance as part of bird strike prevention measures. The Israeli concept of aircraft and birds sharing the air is now appreciated worldwide. Further development of this approach, and extension over the whole Middle East, would not only improve flying safety, an obvious matter of short term self-interest. Through its educational and symbolic value, it also contributes to our ultimate safety, a sustainable and peaceful world

Sincerely,
Drs. Luit Buurma
Chairman of the International Bird Strike Committee (IBSC)

Honored Seminar Delegates,

The Faculty of Life Sciences at Tel Aviv University has been leading biological research in the field in Israel for more then four decades. Many of these studies played a leading role in nature conservation in Israel. Scientists from Tel Aviv University were among the pioneers and founders of the Society for the Protection of Nature in Israel (SPNI), in the beginning of the 1950's, and the Nature and National Parks Protection Authority a decade later. Therefore, it is a great honor to host together with the Israel Air Force and the SPNI, the International Seminar on Flight Safety and Birds in the Middle East. The International Center for the Study of Bird Migration at Latrun initiated and led the seminar's organization. Through Tel Aviv University, we are promoting the center's scientific activities, which have had an active role in reducing the number of pilots injured by birds as well as resulted in significant savings to the national defense budget. We feel that the seminar will also play an important role in promoting the peace process in the region. I believe that in the next few years the air forces in the Middle East will cooperate with one another and provide an excellent example of applied research to the rest of the world.

Wishing you all an enjoyable seminar,

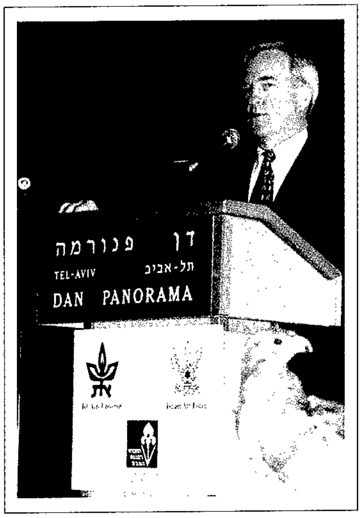
Prof. Nili Cohen
Rector of Tel Aviv University

Dear Colleagues,

The Society for the Protection of Nature in Israel (SPNI) is the largest non-governmental organization (NGO) in Israel which for 46 years has lead struggles to protect our unique natural environment, flora and fauna. Bird migration is one of the subjects that has captivated human imagination since the beginning of time. In 1984, a joint research project was initiated by the SPNI together with the Israel Air Force and Tel Aviv University. The project's results significantly reduced collisions with birds in the Israel Air Force. This was a unique model where cooperation between civil and military organizations delivered results we are all proud of. This seminar is another important step in promoting regional cooperation. I am confident that the model developed in Israel will be also be developed by our colleagues in Jordan, by the Royal Society for the Conservation of Nature in cooperation with the Royal Jordanian Air Force as well as in Turkey by the DHKD in cooperation with the Turkish Air Force.
The SPNI will continue its efforts to promote nature conservation on a regional level, rather than as localized projects, providing a bridge for cooperation between people to help sustain a better environment and brighter future.
Welcome to Israel and enjoy the seminar,

Dr. Shimson Shoshani
Chairman of the Board of the Society for the Protection of Nature in Israel

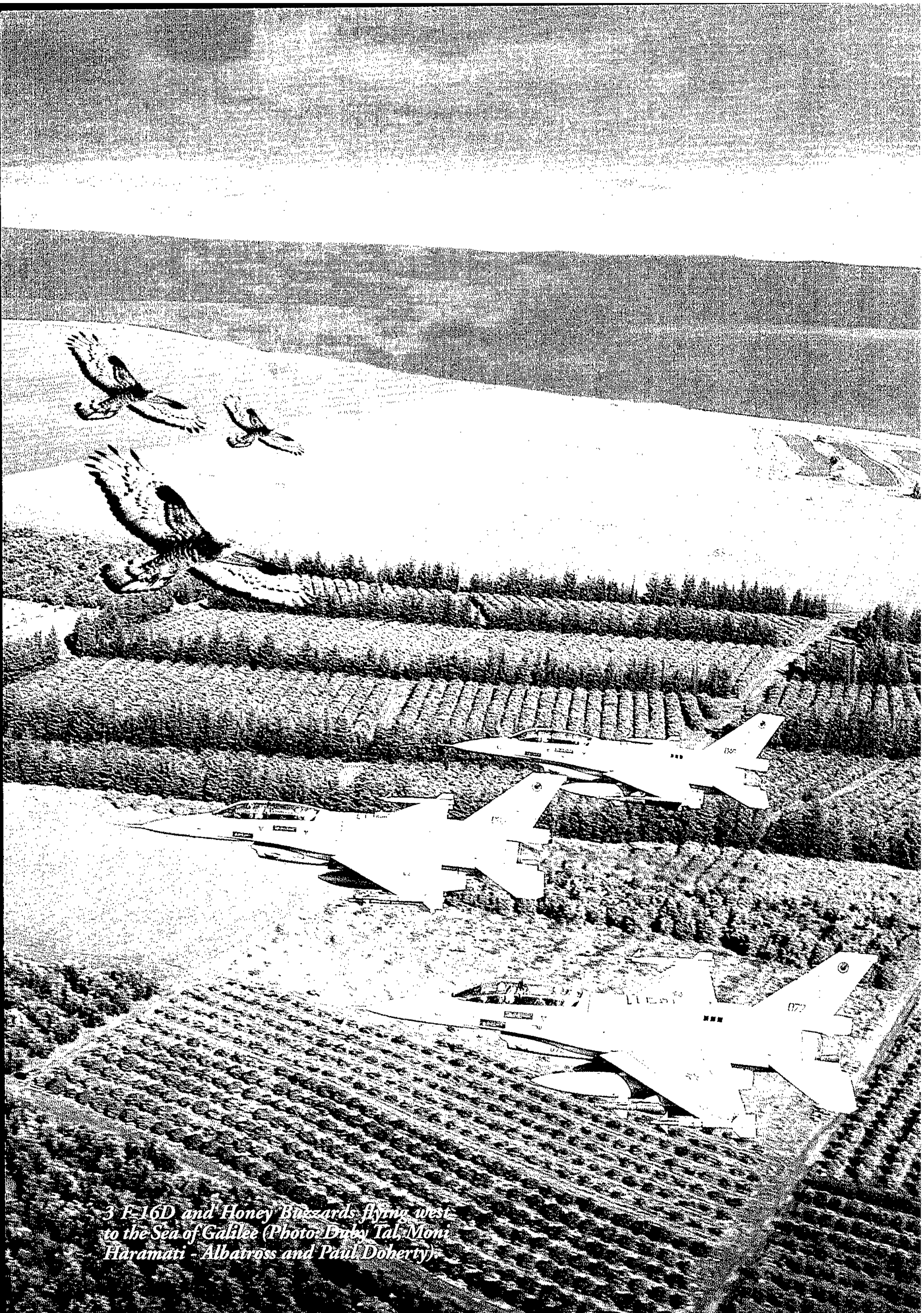
החברה
להגנת
הטבע



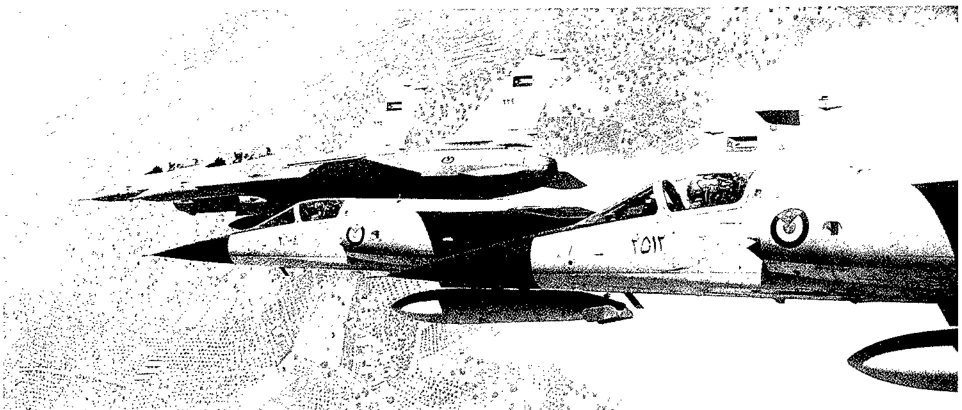
Ladies, Gentlemen, Respected Guests,

The men and women of Lockheed Martin are proud to be a sponsor of this important and unique seminar. It is important because it involves improving the safety of flying operations through the work of international scholars and experts, studying and cooperating on the shared use of the airspace - shared between man and his flying machines and the birds. It is unique because of the imaginative technical approaches to the challenge combined with the essential cooperation among the regional air forces. Forces, and our universal concern for protecting the environment. Lockheed Martin is privileged to be playing a role in the success of this mission.

General (Ret.) James Jamerson
Vice President, International Programs, Lockheed Martin

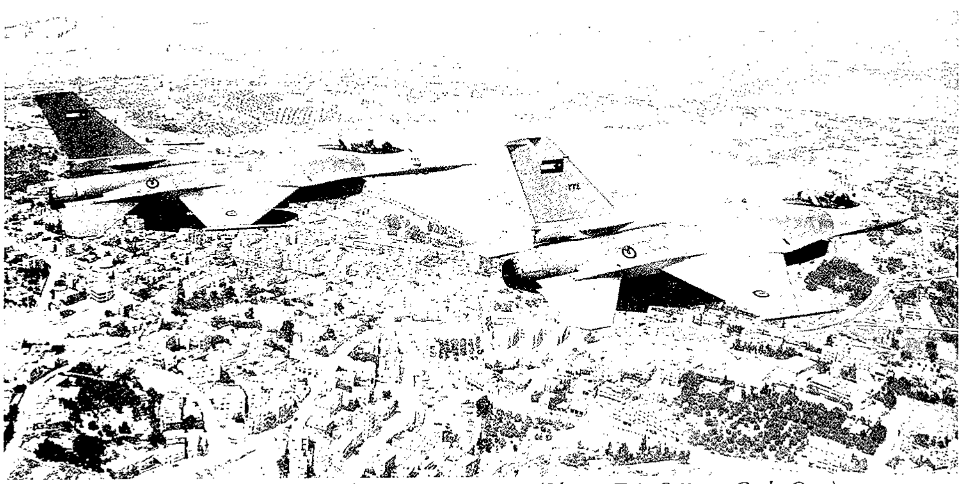


3 F-16D and Honey Buzzards flying west to the Sea of Galilee (Photo: Duby Tal, Moni Haramati - Albatross and Paul Doherty).



Royal Jordanian Air Force planes flying over Jordan (Photo: Eric Stijger, Code One).

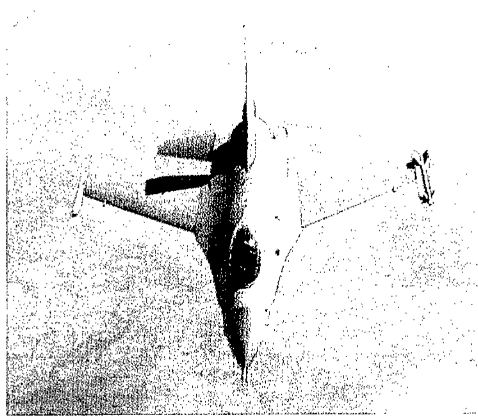
Lanner Falcon (Photo: William S. Clark).



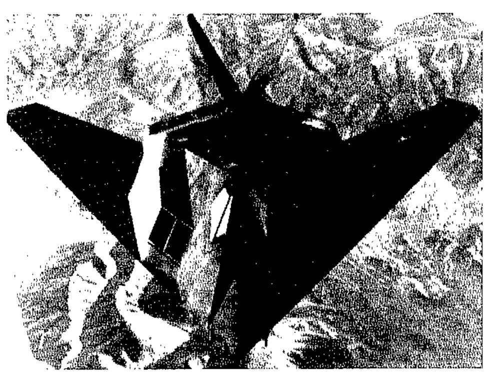
Royal Jordanian Air Force F-16's Flying over Amman (Photo: Eric Stijger, Code One).

Above: *Strategic Bomber B1B in Flight (Photos: USAF).*

Remains of a B1B which was hit by a single pelican, crashed in Texas and 3 air crew were killed.



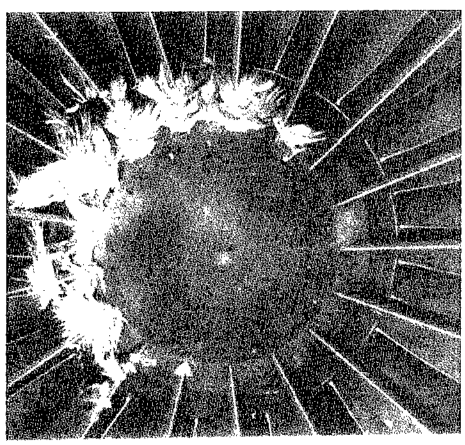
F-16



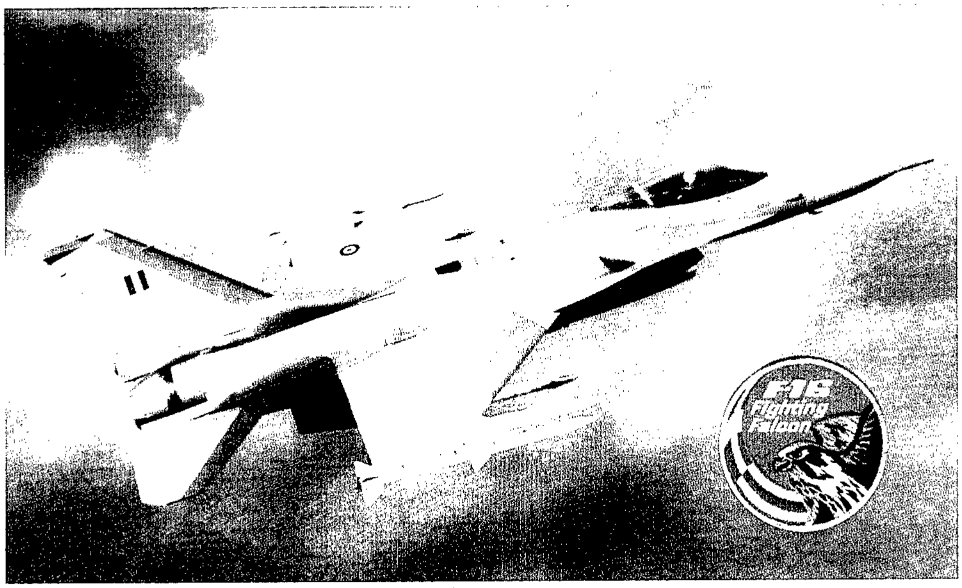
F-117A.

Turkish Air Force F-16s flying over Turkey.

Air refueling maneuver

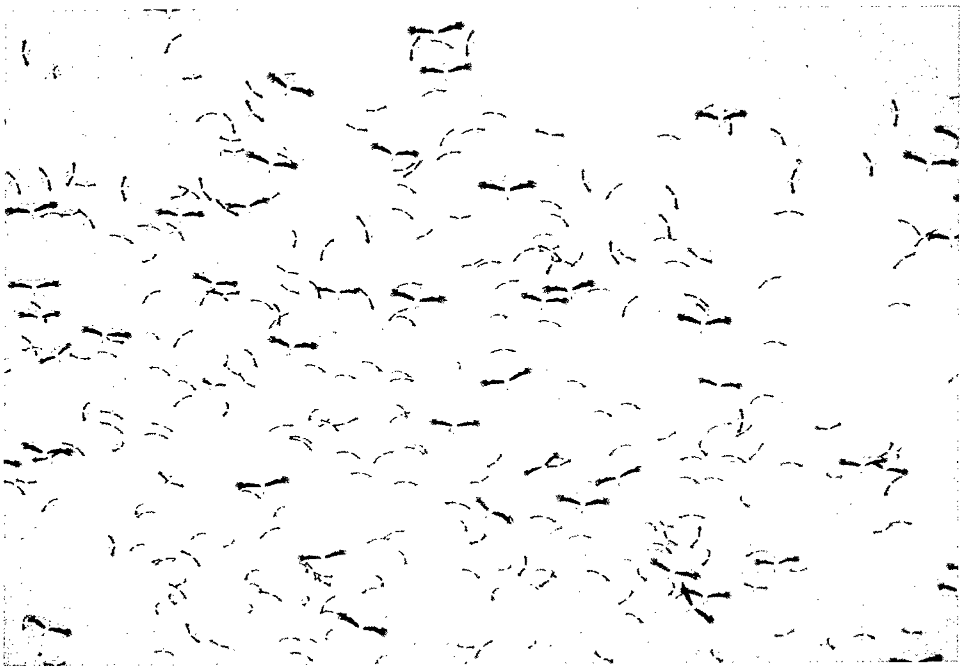


Feather remains of a collision with birds in the Turkish Air Force

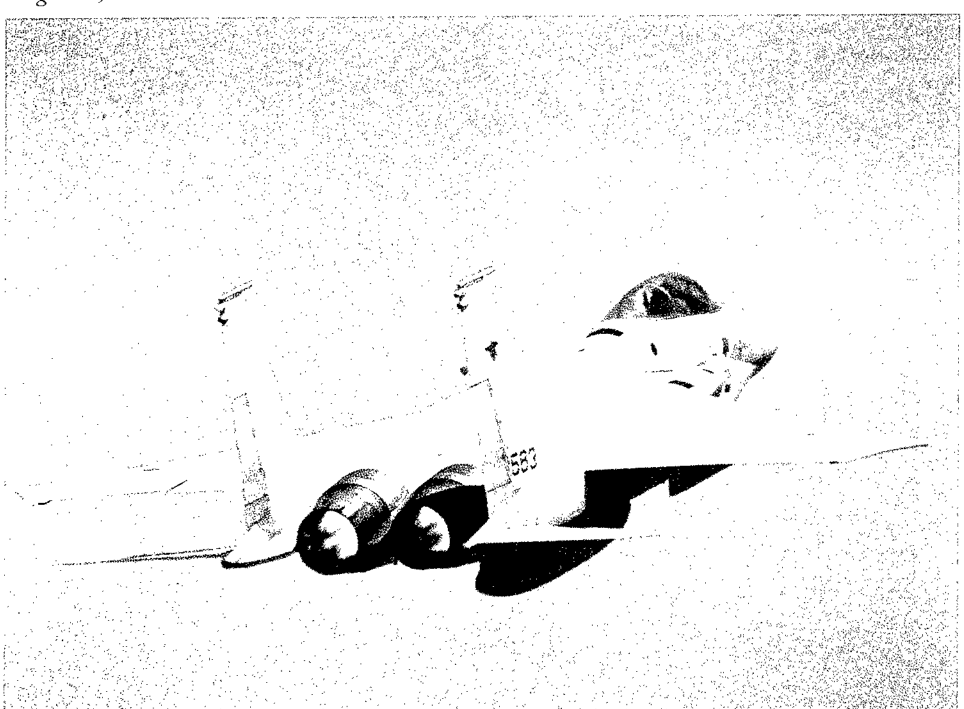


F-16 of the Hellenic Air Force (Courtesy: Code One).

This F-5 A/B (Hellenic Air Force) was scheduled to fly a CPM mission, and in an altitude of 2000 feet a bird strike occurred with simultaneous compressor stall of No. 1 engine. The crew successfully bailed out in very low altitude resulting in the destruction of the aircraft.



Above: *About 600,000 white storks migrate over the Middle East twice a year (Photo: Dick Forsman).*
Below: *An Israeli F-15 takes off. On August 10, 1995 the IAF lost an F-15 and both the pilot and the navigator were killed, from a migrating stork which penetrated the left engine (Courtesy: IAF magazine).*



FORWARD

Until the beginning of the century, birds (together with insects and bats) ruled the skies for millions of years. Only about 96 years ago, at the beginning of aviation, human beings succeeded in taking a dramatic step by sharing the third dimension with the birds. Anyone who has had the pleasure of flying an aircraft will never forget the uplifting feeling of the wheels leaving the runway and overcoming the forces of gravity, a feeling hard to put into words. Those people fortunate enough to sit in any type of glider and ride a thermal together with thousands of migrating storks, pelicans or eagles, being pulled up, wing tip to wing tip with the birds, while the only sound is the wings of the glider or the birds cutting the air, cannot avoid feeling exhilarated by what most people only dream of, flying like birds.

Towards the end of the second millennium, the conflict between birds, military and civilian aviation has increased dramatically for several reasons:

(1) The globe has become much "smaller" with the help of aircraft that have become an integral part of our lives. The rate of takeoffs and landings has increased significantly, concomitantly raising the risk of air collision with birds. (2) Military and civilian aircraft fly much faster and therefore the impact and damage to aircraft has increased significantly. (3) Two decades ago a jet fighter cost only a few million dollars, today the cost has increased two-fold or more, and with it the potential loss from a collision. Today, such an accident can result in damage costing hundreds of millions of dollars, not including the loss of lives. (4) Air forces around the world have stopped training in their airspace only and now train in wide regions spanning several continents.

During the last two decades there has been an increase in the knowledge being collected to solve the conflict between birds and flight safety. The International Bird Strike Committee (IBSC) is an organization that meets every two years, with representatives from dozens of military and civilian organizations from around the world devoted to solving the conflict. The Israeli Air Force has dealt with the problem seriously since 1983 when the Sinai Peninsula was returned to Egypt.

Through joint research projects between the Israeli Air Force, The Society for the Protection of Nature in Israel and Tel Aviv University a great deal of knowledge has been obtained on bird migration and used to significantly decrease damage to military aircraft, particularly from migrating birds. With the advancement of the peace process in the region and the improved cooperation between the Royal Jordanian, Turkish, Israeli and United States Air Forces, it seems only natural that the project "Migrating Birds Know No Boundaries" should be used as one of the first concepts to develop regional cooperation aimed at solving the bird and flight safety conflict. The same migrating birds cross the borders of several countries in the region within one to two days. Within the framework of the seminar, we plan to share the vast experience that has been acquired around the world with representatives of the regional air forces and discuss plans for cooperation in the Middle East, which was once a battlefield. The Middle East can hopefully become a model for cooperation between regional air forces and other areas around the world.

Seminar objectives:

1. To present recent research and programs used in the field of birds and flight safety around the world.
2. To promote regional cooperation under the slogan "Birds Know No Boundaries", which will help promote the peace process in the region.
3. To prepare an operative work proposal to promote the issue.

I would like to take the opportunity to personally thank all those people that have helped make this seminar a success:

The Israel Air Force Commander Maj. Gen. Eitan Ben-Eliahu, Deputy Commander of the Israel Air Force Brig. Gen. Avner Nave, Head of Command of Control Units Headquarters Col. Benny Cohen, Head of Command of Air Force Safety and Inspection Directorate Col. Tamir Safra, and Lt. Col. Ra'anan Cohen. To the staff of Tel Aviv University and the Society for the Protection of Nature, Judy Shamoun-Baranes, Yael Mandelik and Hadas Zitolovsky for their long hours of work to promote the seminar and to Einav Paz and Shira of Arnon Paz Cooperation. To Prof. Boaz Moav, Head of the Zoology Department and Prof. Yoram Yom-Tov.

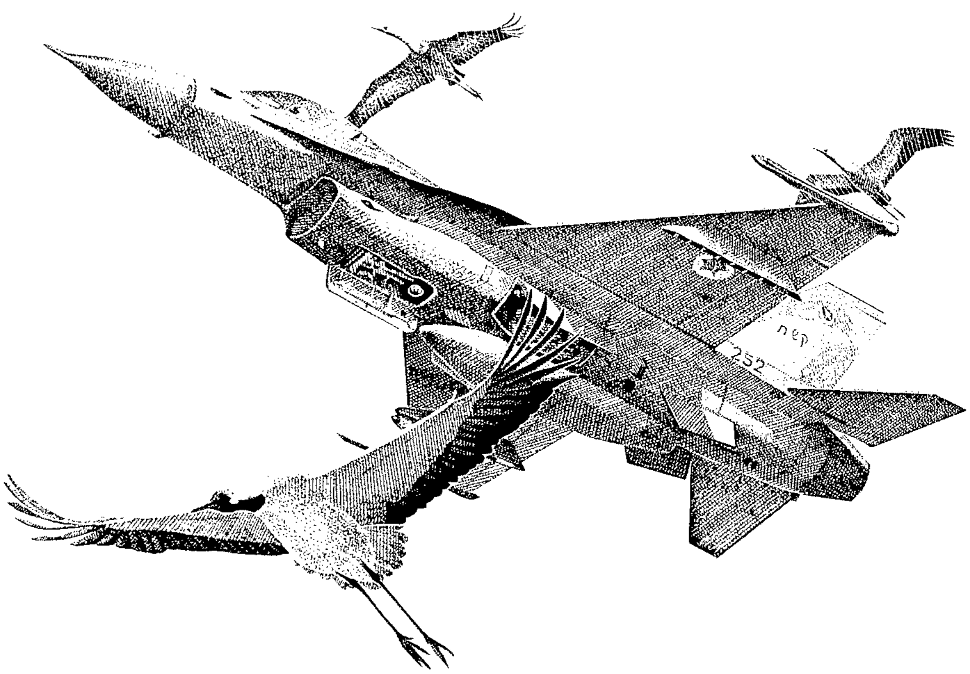
I would like to extend special gratitude to all the public and private organizations for their contribution to the success of this seminar, seeing it as an important step in improving flight safety and especially the peace process in the region:

To Lockheed Martin and especially Brig. Gen. (ret.) Joshua Shani who made a central contribution to making the seminar a success, to General Electric Vice President Lorraine Bolsinger, the European Office of Aerospace Research and Development, Air Force Office of Scientific Research, United States Air Force Research Laboratory – especially to Lt. Col. Mark Smith, to the President of the Stork Foundation, Mrs. Hiltrud Oberwelland, to the General Director of El Al, Brig. Gen. (ret.) Yoel Feldshau. To the Israel Space Agency, the Ministry of Science and its director Aby Har-Even, to the Israel Airports Authority and especially to its General Director Avi Koskelitz, Uri Orlev and Yair Ganot. To Moshe Yanai, Vice President of Engineering, EMC^2, who has contributed to the International Center for the Study of Bird Migration at Latrun since it was established. To the Samis Foundation and especially to Mr. Barry Ernstaff and last but not least to the staff of the Armored Memorial Association and especially to Maj. Gen. (ret.) Musa Peled, Chairman of the Board, and Brig. Gen. (ret.) Menashe Inbar, General Director, To Miriam Feinberg-Varmus for the professional English Editing, to Meir & Asaf Billet for the professional work and dedication.

We would like to wish everyone a successful and fruitful seminar, with the hope that together we can promote flight safety in the Middle East for the people and the birds.

Dr. Yossi Leshem
Yael Mandelik
Judy Shamoun-Baranes

Seminar Program



Birds and Flight Safety in the Middle East 25/4/99-29/4/99

Day 1: 25/4/99 - Sunday

13:00 - Registration – Dan Panorama Hotel, 10 Kaufman St., Tel Aviv

19:30 – 20:30 Social gathering, cocktails and buffet

20:30 – 21:30 Opening Ceremony of the seminar:

Opening video "Faster Than the Wind" (Aerobatic displays of birds and the four air forces)

Music and vocals by the Israel Air Force band and singers

Greetings:

Maj. Gen. (ret.) David Ivry, Chairman of the Council for National Security (former Israel Air Force Commander)

Maj. Gen. Eitan Ben-Eliahu, Israel Air Force Commander

Brig. Gen. Murat Bulgan, Base Commander & Representative for the Turkish Air Force Command

Col. Pilot Malik Salamah Habashneh, Head of Flight Safety Unit, Royal Jordanian Air Force

Col. Roger C. Craig, Vice Commander Headquarters Air Force Safety Center, United States Air Force

Gen. (ret.) James Jamerson, Vice President of Lockheed Martin

Prof. Yair Aharonowitz, Dean for Research, Tel Aviv University

Dr. Shimshon Shoshani, Chairman of the Board of the Society for the Protection of Nature in Israel

Master of ceremonies: **Dr. Yossi Leshem,** Director of the International Center for the Study of Bird Migration at Latrun

Video documentary: "**Flying with the Birds in Peace**"

Closing song: **Israel Air Force Band and singers**

Day 2: 26/4/99 - Monday

Session 1: **Chairman – Gen. (ret.) James Jamerson, Vice President** of Lockheed Martin

8:30 - 8:50 Dr. Yossi Leshem, Director of the International Center for the Study of Bird Migration at Latrun, Tel Aviv University and SPNI, Chairman of the IBSC Statistics Working Group

Developing a Real Time Warning System in the Middle East - from Vision to Reality

8:50 - 9:10	**Dr. Luit Buurma,** Chairman of the International Birdstrike Committee & Royal Netherlands Air Force chief biologist **RNLAF - Two Decades of Treating Bird Hazards and Developing an International Military Birdstrike Database.**
9:10 - 9:30	**Dr. William Seegar,** Edgewood Research, Development and Engineering Center **The Use of Satellite Telemetry to Study Long Distance Bird Migration**
9:30 - 9:50	**Dr. Harlan Shannon,** University of Maryland **Bird Flight Forecast and Information System**
9:50 - 10:10	**Adam Kelly** – Geo-Marine Project Manager **The Avian Hazard Advisory System (AHAS) Using NEXRAD Radars**
10:10 - 10:30	**Prof. Bruno Bruderer** - Swiss Ornithological Institute, Sempach & Chairman of the IBSC Remote Sensing Working Group **Three Decades of Tracking Radar Studies in Europe and the Middle East**
10:30 - 11:00	**Coffee break**

Session 2: **Chairperson – Mrs. Lorraine Bolsinger,** Vice President of Military Market, General Electric

11:00 – 11:20	**John Thorpe,** honorary Chairman of the International Birdstrike Committee (IBSC) **Review of 100 Years of Military and Civilian Birdstrikes**
11:20 – 11:40	**Dr. Richard Dolbeer,** US Department of Agriculture **Aerodrome Bird Hazard Prevention: Case Study at John F. Kennedy International Airport**
11:40 – 12:00	**Bruce MacKinnon,** Aerodrome Safety Branch Transport Canada & Chairman of the IBSC Public Relations working group **The Role and Value of Awareness Programs in Reducing Bird Hazards to Aircraft**
12:00 – 12:20	**Prof. Yoram Yom-Tov,** Department of Zoology, Tel Aviv University **The Fascination of Bird Migration**
12:20 – 12:35	**Mr. Robert Griswold,** General Manager of Military Engines, General Electric **Focus on Engine Bird Ingestion Capability**
12:35 – 14:00	**Lunch** – Sponsored by the Israel Airports Authority (IAA), greetings by **Mr. Avi Kostelitz,** IAA Director General.

Session 3: **Chairman – Aby Har-Heven,** General Director of the Israel Space Agency, Ministry of Science

14:00 – 14:15 **Lt. Col. Eric,** Commanding Officer of Flight Safety Branch, Israel Air Force

Birds and Flight Safety in the Israel Air Force

14:15 – 14:30 Turkish Air Force representative

14:30 – 14:45 Jordanian Air Force representative

14:45 – 15:00 **Maj. Gerald Harris,** Chief of Safety, Plans and Programs Division, United States Air Force Europe

Bird Aircraft Strike Hazard (BASH) in the United States Air Force, Europe

15:00 – 15:15 Hellenic Air Force representative (not yet confirmed)

15:15 – 15:25 **Judy Shamoun-Baranes** - Feather identification specialist, Tel Aviv University & SPNI

Bird Remains Identification System (BRIS) - from a bi-national to a Global Database

15:25 – 15:40 **Dan Alon** - Director of the Israel Ornithological Center, SPNI

From a Local to Regional Ground Survey Network and its Application in Flight Safety

15:40 – 16:00 **Dr. Yossi Leshem** - Director of the International Center for the Study of Bird Migration at Latrun, Tel Aviv University, SPNI

15 Years of Applying Migration Research in the Israel Air Force

16:40 – 17:30 Drive to Latrun

17:30 – 19:00 Laying of a ceremonial wreath, tour around the Armored Corps Memorial Site, the Russian radar and a demonstration of the educational Internet program **"Migrating Birds Know No Boundaries"** in the computerized classroom (by **Dr. Miri Rosenboim**).

19:15 – 21:00 **Festive dinner in the open amphitheater at Latrun**

Program:

Quartet – Educational Corps, I.D.F.

Dinner

Greetings: **Maj. Gen. Gideon Shefer,** Vice President of the Air Force Association

Maj. Gen. (ret.) Musa Peled, Chairman of the Armored Forces Memorial Association

M.K. Shimon Peres, President of the Peres Center for Peace

Mrs. Hiltrud Oberwelland, President of the Stork Foundation

Day **3: 27/4/99 - Tuesday**

Session 4: **Chairman – Lt. Col. Mark Smith,** European Office of Aerospace Research and Development, USAF

8:30 - 8:50 **Lt. Col. Dr. Russell Defusco,** USAF Academy

The United States Bird Avoidance Model (BAM)

8:50 - 9:10 **Dr. Luit Buurma** - Chairman of the IBSC, RoyalNetherlands Air Force chief biologist

The Bird Avoidance Model - Interface Between Safety and Conservation

9:10 - 9:25 **Col. Benny Cohen,** Command of Control Units Headquarters, IAF

Coordinating military flyways within Israel's limited air space

9:25 – 9:40 **Judy Shamoun-Baranes,** Tel Aviv University & SPNI

Development of a GIS-based Bird Migration Model for the Middle East

9:40 – 9:55 **Adiv Gal,** Tel Aviv University

A New Technique for Studying Nocturnal Bird Migration

9:55 - 10:10 **Les Lemon,** Lockheed Martin

10:15 - 10:45 **Coffee Break**

10:45 - 12:30 **Three parallel working group meetings and discussions**

I. Chairmen: **Prof. Bruno Bruderer & Dr. Luit Buurma**

Developing a Radar Network in the Middle East.

II. Chairmen: **Lt. Col. Dr. Russell Defusco & Judy Shamoun-Baranes**

Developing Regional Bird Avoidance Models.

III. Chairmen: **Lt. Col. Raanan & Maj. Gerald Harris**

Implementing Bird Issues in Military Flight Safety Units.

12:30 – 13:30 Drive to Tel Nof Air Force Base

13:30 – 14:20 **Lunch at Tel Nof Air Force Base** – hosted by Col. Omer, Deputy Base Commander

14:25 Drive to Operation Room of F-15 Flight Squadron

14:30 - 14:45 **Col. Omer,** Deputy Base Commander

Military operations at Tel Nof Air Force Base

14:45 - 15:00 **Commander of F-15 Squadron** - Briefing of squadron operations and flight safety

15:00 – 15:20 **Dr. Eyal Shay,** Israel Nature and National Parks Protection Authority

Factors Affecting Bird Hazards in and Around Israeli Aerodromes

15:20 – 16:30 **Tour of base, observing fighter aircraft activity, demonstration by the Bird Control Unit on runways**

16:30 – 17:00 Drive to Ben Gurion Airport

17:00 – 18:30 **Ben Gurion Airport** - hosted by **Yair Ganot & Eilon Tal,** Israel Airports Authority: Demonstration by Bird Hazard Control Unit, visit to IAF Bird Warning Center at the radar center, return to Tel Aviv.

20:00 **Tour through the Old City of Jaffa**

20:45 **Dinner at Magenda,** a Middle Eastern restaurant.

Hosted by: **Brig. Gen. (ret.) Yoel Feldshaw,** General Director of El Al Airlines (not yet confirmed)

Day 4: 28/4/99 - Wednesday

06:00 **Early breakfast**

06:45 – 08:00 Drive to Jerusalem

08:00 – 08:45 **Observing bird ringing** at the Jerusalem Bird Observatory located at the Knesset Rose Garden. Guided by: Amir Balaban, Director of the Jerusalem Bird Observatory.

09:00 – 12:00 **Tour of Jerusalem:** the city sacred to the three monotheistic religions (guided by Rinat Doshinsky, SPNI Jerusalem Field Study Center soldier).

12:00 – 13:30 Drive to Kibbutz Kfar Rupin

13:30 – 14:30 **Lunch at Kibbutz Kfar Rupin** sponsored by the Beit Shean Regional Council. Greetings by the Mayor of the Regional Council, **Mrs. Yael Shaltieli.**

14:30 – 18:00 **Tour through the fish ponds and breeding colony of egrets, and cormorants on the Jordan – Israel border, barn owl project.**

18:00 Drive to accommodations at Howard Johnson's Hotel Galei Kinneret, Tiberias, near the Sea of Galilee.

19:30 **Dinner at the Galei Kinneret Hotel ,** Tiberias, sponsored by the **Israel Nature and National Parks Protection Authority** with greetings by **Dr. Avi Perevolotsky** - Chief Scientist and **Aharon Vardi** - General Director.

Evening: Moonlight boat ride on the Sea of Galilee.

Day 5: 29/4/99 - Thursday

6:00	**Early Breakfast**
6:30 – 10:15	Trip to the **Gamla Nature Reserve** to observe the nesting colony of Griffon Vultures and bird migration. Guided by **Dr. Ofer Bahat,** Director of the Griffon Vulture Project in cooperation with the **Israel Electricity Company.**
10:00 – 11:00	Drive to Hermon Field Study Center
11:00 – 13:00	Lecture room at Hermon Field School: **Summarizing the seminar and Establishing Guidelines for Continued Cooperation in the Future.**
13:00 – 14:00	**Lunch:** Festive lunch to conclude the seminar at the SPNI Hermon Field Study Center.
14:00	**End of seminar.** Transportation will be provided to the Hussain Bridge (Jordan delegation), Ben Gurion Airport and Dan Panorama Hotel, Tel Aviv.

Partial List of videos on birds and flight safety that will be shown en-route during the seminar:

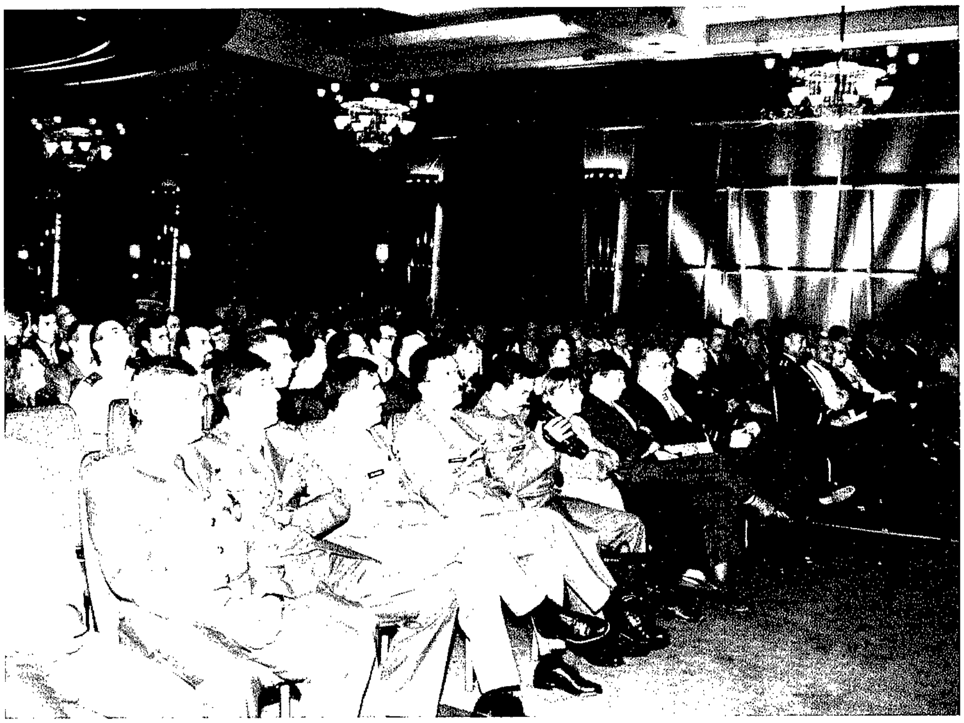
- **"The Negev Arava Migration Project"** – Prof. Bruno Bruderer, Summary of radar observations of bird migration near Hazeva and Sede Boqer, Israel in 1991/92
- **"Crossed Paths"** – Bruce MacKinnon
- **"Flying with the Birds"** – Dr. Yossi Leshem

The drawings in the book by James Smith

Some nice moments to remember... With great hope for peace and flight safety for the benefit of the people and the birds in the Middle East

White Storks flying peacfully over the Holy City of Jerusalem.
Painting: *Martin Rinik, based on aerial photo by Duby Tal and Moni Haramati, Albatross.*

Nice people, good food and excellent wine in the opening ceremony at Dan Panorama Hotel in Tel Aviv.
Above: *The Turkish delegation is having difficulties in deciding what comes first...*
Below: *(left to right) Mr. Bruce MacKinnon, Canada, Dr. Richard Dolbeer, Dr. Bill Seegar and Harlan Shannon, USA, tasting Middle East wines... (Photos: Yigal Pardo)*



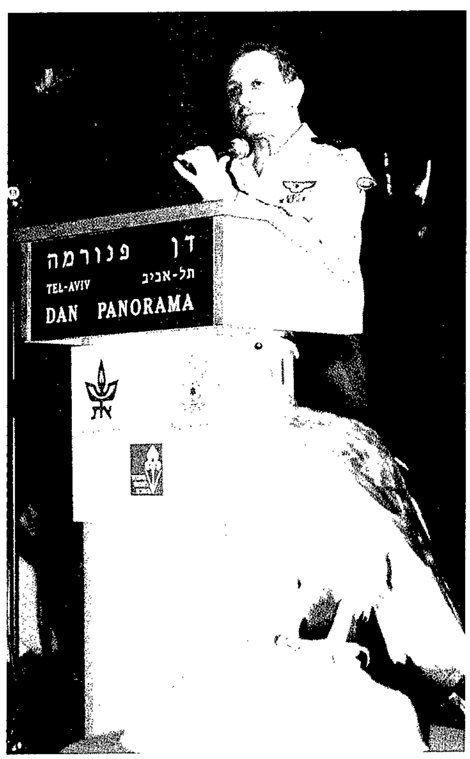
Above: *The crowd attending the opening ceremony.*

Below: *(right to left) Maj.Gen. Dan Halutz, Chief Operation Branch, IDF, Lt. Col. Yilmaz Goksen and Brig.Gen. Murat Bulgan, Turkish Air Force. (Photos: Yigal Pardo)*

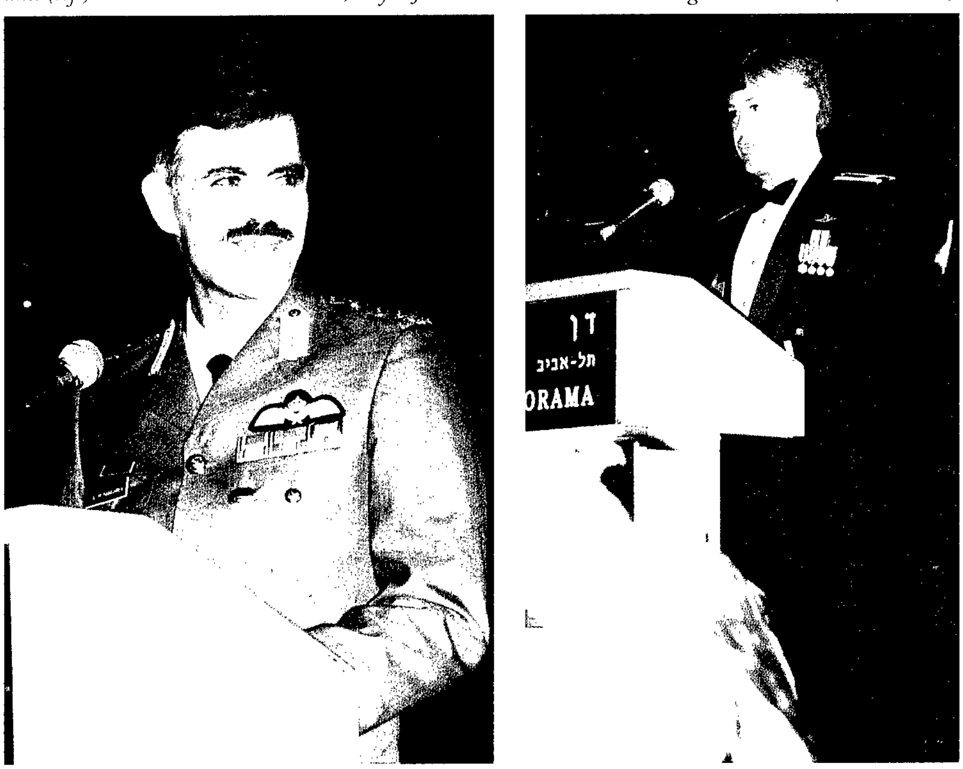
Above: *Lt. Col. Dr. Russell Defucso, USAF Academy, and well-known expert on USAF bird safety issues, examining IAF flight-safety problems. Behind Russ is Adam Kelly, Geo-Marine BASH Project Manager, USA.* ***Below:****(right to left) Brigadier General Avner Naveh, Chief of staff, IAF, Mrs. Lorraine Bolsinger, Vice President of General Electric, Mrs. Lili Naveh and General (Ret.) James Jamerson, Vice President Lockheed Martin. Second row: Luit Buurma, Royal Netherlands Air Force.*

Above: *Maj. Gen. Dan Halutz, who was appointed in December 1999 as the next IAF commander, at the opening ceremony of the seminar which took place in the Dan Panorama Hotel. With him is Mr, Adi Maor, the hotel's General Manager.*
Below: *Representatives of the academic community (right to left): Prof. Yair Aharonowitz, Vice President and Dean for Research, Tel Aviv University; Prof. Yoram Yom-Tov, who has been involved for two decades in migration research; Mrs. Shlomit Yom-Tov, and Prof. Heinrich Mendelssohn, Father" of zoologists, (Phtos: Yigal Pardo)*

***Above:** Major General D. Athanassakos, Inspector-General Hellenic Air Force and his officers examining the exhibit of IAF and SPNI "Flying With the Birds" before the ceremony.*
***Below:** Major General Ben-Eliahu (right) and Major General (Ret.) David Ivry (left) making his address at the opening ceremony. (Photos: IAF)*



Above: *Brigadier General Murat Bulgan, Base Commander of the Turkish Air Force addressing the audience.* ***Below:*** *(Right) Colonel Roger C. Craig, Vice Commander of the US Air Force Safety Center and (left) Colonel Malik Habashneh, Royal Jordanian Air Force addressing the audience. (Photos: IAF)*



Above: *(right to left) Colonel Malik Habashneh, Royal Jordanian Air Force, Major General Eitan Ben-Eliahu, Commander of the Israeli Air Force, Major General (Ret.) David Ivry, Chairman of the Council for National Security and Major General Dan Halutz, Chief of the Operations Branch, Israel Defense Force. (Photos: Yigal Pardo)*

Above: *Brigadier General Bulgan (Turkey) and Colonel Roger Craig USAF below the armored Memorial Emblem at Latrun.* ***Left:*** *The wreath laid near the Wall of the Names at Latrun.*

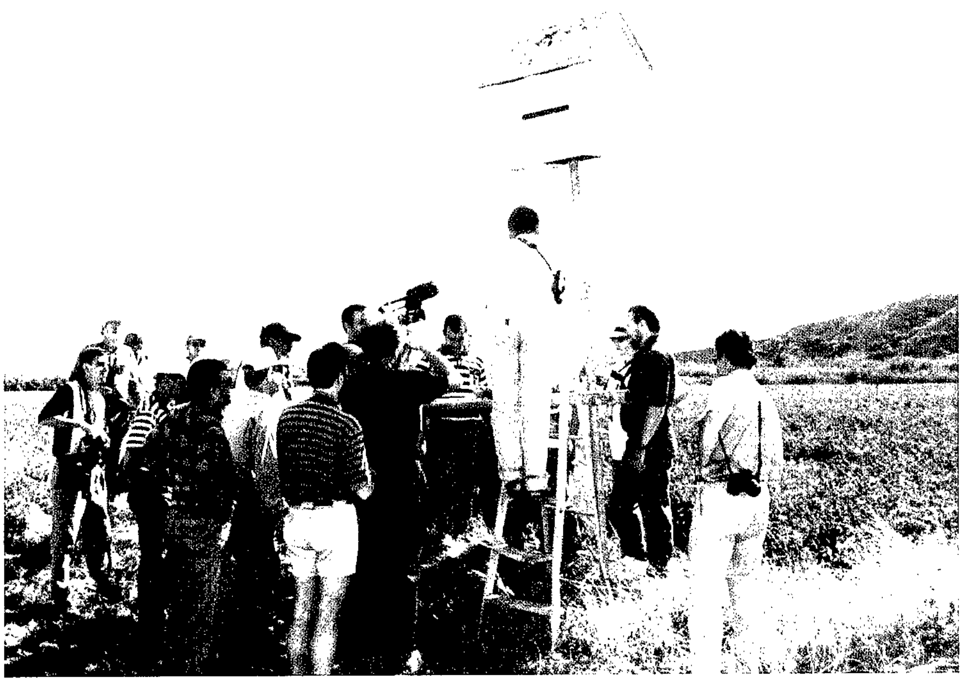
Above: *Participants of the Seminar at Latrun (behind the Russian bird and weather radar).*
Below: *Participants at the educational computerized classroom at Latrun, in which teachers and students can follow migrating birds with transmitters intercepted by satellite via the internet. (Photos: Yigal Pardo)*

Above: *Mr. Shimon Peres, the former Prime Minster of Israel and one of the most important leaders of the peace process in the Middle East, was the guest of honor in the Gala dinner at Latrun. Mr. Peres receives from Brigadier General Bulgan, Turkey, Colonel Habashneh, Jordan, Colonel Craig, USA and Mrs. Hiltrud Oberwelland, President of the Stork Foundation, Germany an enlargement of a drawing of a Bearded Vulture (in Hebrew: Peres) painted by Trevor Boyer.*

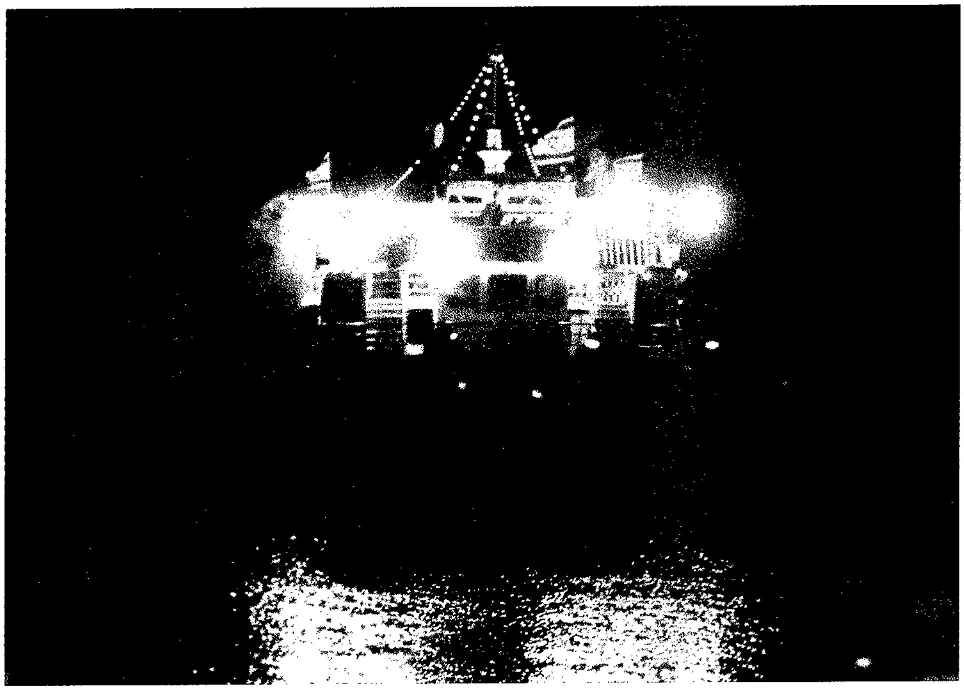
Below: *Yossi Leshem expresses on behalf of all the participants, the highest appreciation to Mr. Shimon Peres, who participated in the Gala dinner even though it was the busiest time in his campaign for the coming elections. Leshem wears a tie with the Royal Jordanian Air Force Emblem, which he received as a present from the commander of the R.J.A.F. (Photos: Yigal Pardo)*

Above: *Participants in front of the Dome of the Rock, the Old City of Jerusalem.* ***Below:*** *Colonel Habashneh watching the huge Heron, Egrets and Pigmy Cormorants colony, nesting on the Jordan River, through the wires at the border between Jordan and Israel (yellow-red sign read: Beware Mines!). (Photos: Israel San Ltd.)*

Visiting the Ringing Station of the Jerusalem Bird Observatory, located on the grounds of the Israeli Knesset (Parliament). As far as we know, this is the only parliament in the world which has a permanent Ringing Station on its land. ***Above:*** *Gideon Perlman holding a Hoopoe which was just ringed.* ***Middle:*** *A "peep-show" in the Holy City-watching and filming the Hoopoe's nest, through a hole in the wall. Amir Balaban, the Director (with sunglasses) who arranged the show... (Photos: Israel San Ltd.)*



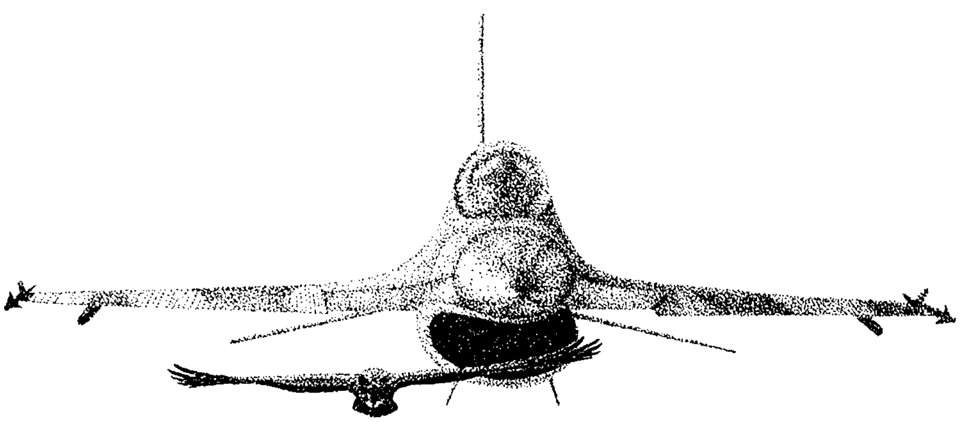
Above: *Kibbutz Sde Eliyahu and Kfar Rupin have established nesting boxes in the Beit Shean Valley for Barn Owls, to attract them to feed on the rodents in their fields, in order to avoid any use of pesticides in developing organic agriculture.* ***Below:*** *Prof. Bruno Bruderer, sempach (Switzerland) gives the audience academic explanations on the Barn Owl chick. (Photos: Israel San, Ltd.)*



***Above:** "Grand Finale" party of the International Seminar was celebrated on a boat, sailing at night on the Sea of Gallilee (Lake Kineret). **Below:** Brigadier General Bulgan from the Turkish Air Force demonstrated high maneuvering ability, as good as with his F-16s in the air. Mrs. Oberwelland performs the "Stork Flight". Lieutenant Colonel Mark Smith, US Air Force (in back). (Photos: Yossi Leshem)*

Papers

(In session order)



The Minister of Education, Mr. Yossi Sarid flying with the motorized glider and the migrating storks over Israel and the Pigeon of Peace is leading the whole flock...

Developing a Real Time Warning System in the Middle East; from Vision to Reality

Yossi Leshem
George S. Wise Faculty of Life Sciences
Department of Zoology, Tel Aviv University
Ramat Aviv, Tel Aviv 69978, Israel

Abstract

The Middle East is strategically located at the junction of three continents. As a result, it is a "bottleneck" into which all or a large part of the world population of certain soaring species concentrate during spring and autumn, as well as hundreds of millions of other birds. The concentration of an extremely large mass of birds has created a severe flight safety problem for Israel Air Force aircraft and its pilots. The Israel Air Force (IAF) has developed new flight regulations based on five years of research that have succeeded in reducing the rate of collisions with migrating birds by 76%. Following previous meetings with the Royal Jordanian (RJAF) and Turkish Air Forces it is proposed to develop a regional system of cooperation to be developed by each Air Force but based on one integrated regional system. The idea is to share the large experience gained in the IAF on these issues since 1984, and develop an information system on bird movement collected by a network of birdwatchers, radars and motorized glider flights. The data collected by Argos Satellite which intercepts radio-transmitters attached to soaring birds will also be accumulated within this information system. EMC2, a leading data storage company, has already expressed its willingness to lead this idea.

The IAF is now in the process of purchasing weather and bird radars to develop a real time warning system. The Lockheed Martin radars as well as others are being examined, in order to cover the entire country with a network of these radars. It is proposed to develop a network of the same radars in other countries. Such a network will enable the Turkish Air Force in the autumn to provide real time information to the RJAF and IAF, which can provide the real time data to the Egyptian Air Force. During spring migration, information will be transferred vice-versa from Egypt to Turkey.

As a resolution of this seminar, it is proposed that each Air Force will join forces with local universities, as well as bird and nature conservation organizations to establish new regional working groups, and work to advance regional cooperation. The USAF and other airforces training in the Middle East will be invited to join this initiative.

"...On the path which no eagle knoweth, and which the honey buzzard eye hath not surveyed..." (Job, 28:7)

Introduction

The impressive sight of migrating birds over Israel, in spring and autumn, has already been noted by our ancestors ("Yea the stork in the heavens knoweth her appointed times; and the turtle dove and the swallow and the crane observe the time of their coming", Jeremiah, 8:7).

Israel's location at the junction of three continents - Europe, Asia and Africa - has made it a passage route of international importance for migrating birds of prey and large soaring birds, such as storks and pelicans, both in spring and autumn (Leshem & Yom-Tov, 1996 a,b).

Migrating birds can be divided into two principal groups: those flying actively and those using their gliding abilities (passive flight). The difference between the two groups arises from the changes in the relation between body weight and wing area as the bird grows heavier. The former increases to the third power, whereas the latter only squares itself. Thus, the heavier the bird, the more difficult it is for it to create lift in active flight by muscle power alone. The transition from one group to the other is gradual and a gradient exists between the small, actively flying birds, and the large soaring ones, who can reach a weight of 15 kilograms. Most birds fall into the first category, such as the passerines (Passeriformes), waders (Charadriformes), and many other avian orders. They use fast wing beats to migrate for hours at a time. These birds are also called "sea crossers", since they can fly across large water bodies (such as the Mediterranean) or deserts, in active flight, for many hours, with no rest periods along the way. One of the better known examples is the Quail (Coturnix coturnix), which concentrates in large flocks in southern Europe, southern Turkey, the southern Aegean Peninsula and Italy, preparing to migrate. Before dark, the Quails depart, in order to cross the Mediterranean in one night, thus avoiding a long, roundabout route of hundreds of kilometers.

Large bodies of water, such as the Mediterranean, the Caspian, or Black Sea are an impediment to most soaring birds. They must circumvent them on their way from Asia and Europe, since there are no rising air currents (thermals) over water bodies. As a result, the western European population concentrates over the Straits of Gibraltar (Cramp and Simmons, 1980; Bernis 1980). A small part of the soaring bird population of central Europe crosses the Mediterranean at its narrowest points. The majority of the northern, central, and eastern European populations as well as large parts of the western Asiatic and Caucasian populations, fly along the shortest route which circumvents the Mediterranean. They concentrate in the skies over Turkey, Lebanon, Jordan, and Israel on their way to Africa.

There is good reason for some of the birds of prey to lengthen their migrating route by hundreds of kilometers, avoiding the Mediterranean, by doing so, they achieve maximal

Figure 1: *Soaring bird migration method based on thermal utilization*
Soaring birds "skip" from thermal to thermal, thus covering thousands of kilometers with almost no energy expenditure. Since thermals are formed only during the day, raptors migrate only then, when the air warms up and rises. Towards the evening they land to roost. (Drawing: Tuvia Kurtz)

Below: *Migrating White Storks circling in a thermal while gaining altitude (photo: Ofer Bahat)*

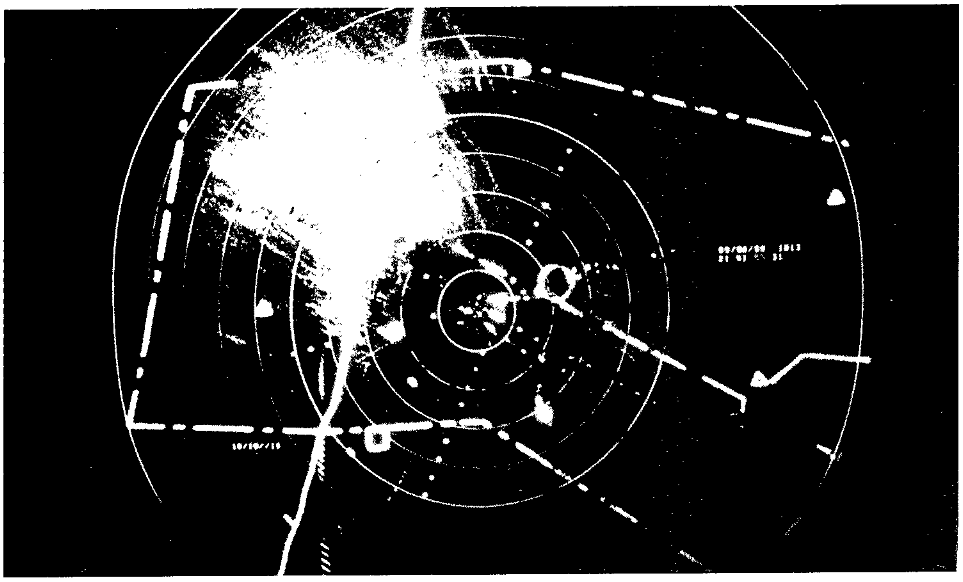
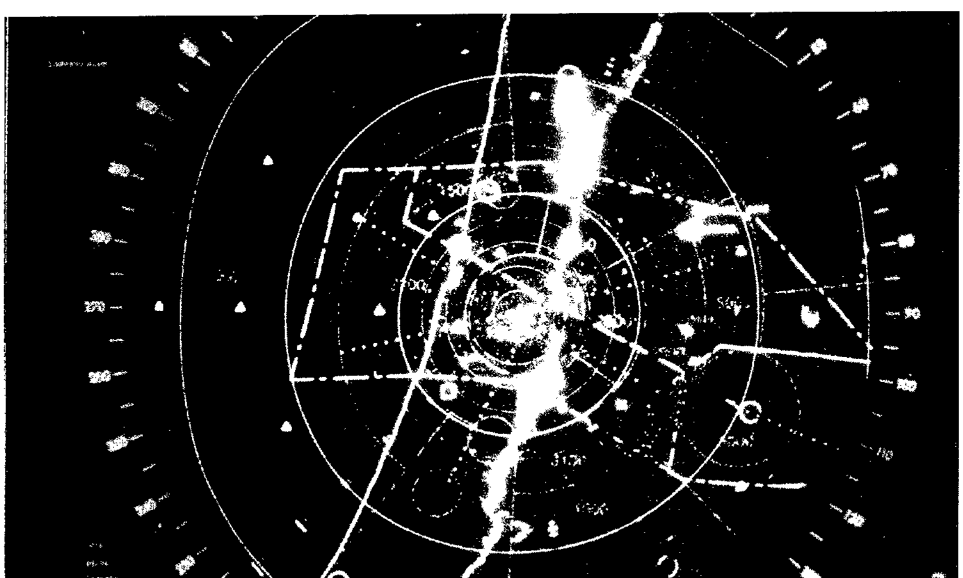


Photo 1: Typical "active migrant" movements, as photographed on the surveillance radar at the Ben Gurion International Airport, on 10/10/88 21:50 (10 minute exposure). The line crossing the radar screen from north to south is the coast line of Israel. In this photo we can see a large mass of birds arriving at night along a broad front, from Cyprus or Turkey(?) and crossing the coastline from northwest to southeast. The front lies between azimuth 260 and 360 degrees, and it is 30x43 km wide!
Photo 2: 27/9/88, typical "passive migrant" movements: a narrow line 90km long of lesser spotted eagles move along the Samarian Mountain slopes from Europe to Africa. The radar operator can receive according to his determination, a radar picture within a range of 60, 30 or 10 miles, locating the flocks from great distances or checking a specific flock in detail within a range of only 10 miles. The topography of Israel, with the Samarian and Judean mountains reaching an altitude of 700-1000 meters, prevents the radar from following most migration in the Jordan Valley, which lies at -400 meters.



energy conservation. Most large raptors, to whom we can add storks and pelicans, are heavy and have long, broad wings which are perfectly adapted to gliding. Due to their large body weight, these birds are unable to fly actively for days at a time with continuous wingbeats as do passerines, for example. They must, therefore, use flight routes over geographical areas where good soaring and gliding conditions exist, making use mainly of rising hot air currents. As a result, raptor migration is concentrated along narrow, long valleys, cliffs and long mountain ranges, where ideal gliding conditions develop, which allow these birds to progress with minimal energy expenditure.

With the help of their long, wide wings, the soaring birds lift off, circling around an invisible axis in the sky, on almost stationary wings, to an altitude where the air mass stops rising. At this point they start gliding, losing height along the way (see fig. 1), until they locate the next thermal visually, (by spotting other raptor or stork groups rising on a "neighboring" thermal), or aided by the extreme sensitivity of their wings and bodies to all changes in air currents.

Pennycuick (1972), compared the migration strategy of the white stork (Ciconia ciconia), as a representative soaring birds, and that of Bonelli's Warbler (Phylloscopus bonelli) as a typical actively flying bird. His data shows that with the stork, the relation between fat consumption during active flight to that in passive flight is 1:23. In the warbler the relation is a mere 1:2.4. This explains the tremendous significance of passive flight to large soaring birds.

Mountain ranges along the coasts of seas or large lakes, are ideal for the formation of rising warm air currents. As a result, the major migration routes in North America lie along three high mountain ranges, which are parallel to the eastern coast (Heintzelman 1986; Kerlinger 1989).

The advantage of Israel and Jordan as an ideal route for migrating raptors lies in its geographical location. The Syrian-African Rift runs the length of the countries, creating optimal conditions for rising thermals, since in this area, it is narrow and altitude differences reaching hundreds of meters exist along the Fault Escarpment. The combination of steep cliffs cut by narrow gorges and the high average temperatures along the Rift, provide a classic migration route for birds of prey and storks. The Lebanese mountains, the Shuf mountain range, the mountains of the Galilee, Samaria, and Judea lie almost parallel to the coastline. This situation also creates good conditions for thermals, which facilitate soaring bird migration.

For the above reasons we can conclude that actively migrating birds:

1. Migrate both during the day and at night.
2. Use direct and relatively short routes to migrate from breeding areas to wintering areas.
3. Cross large water bodies during migration.
4. Store fat before leaving, since active migration uses large amounts of energy.
5. Migrate along a "broad" front and do not concentrate along defined, narrow migratory routes.

We can conclude that "passive" migrants:

6. Migrate only during the day.
7. Increase the total distance covered by migrating along routes with appropriate wind and thermal regimes.
8. Avoid crossing large bodies of water.
9. Do not accumulate and store fat before migrating, since passive flight is very economical energy wise.
10. Migrate along defined and relatively constant routes.

The results of soaring bird migration tracking during the last three decades, both in the Old (Porter and Willis 1985, Bijisma 1987) and New World (Heintzalman 1986, Kerlinger 1989), confirm the above. They all show large soaring bird concentrations converging into straits, in order to avoid crossing water bodies.

Israel's unique location at the junction of three continents makes it an international crossroads for migrating birds: some 500 million birds cross Israel's skies heading south to Africa in autumn, and then flying north to Europe and Asia in the spring.

The convergence of such a tremendous mass of soaring birds, some arriving in concentrated waves of tens and sometimes hundreds of thousands a day, over the limited air space over Israel, has created a severe flight safety problem for Israel Air Force (IAF), aircraft and pilots. The situation worsened significantly when Sinai was returned to Egypt in April 1982. Israel Air Force activity now had to concentrate within the new, narrower borders of the country. Analysis of fighter aircraft-bird collisions in the Air Force between 1972-1982, brought to light five important facts: (a) There had been hundreds of collisions with birds during these years. (b) A high percentage of the collisions occurred during the main migration months - in spring from March - May, and in autumn from August to November. (c) 74% of the most serious collisions, in which aircraft crashed or were seriously damaged (more than a million dollars), occurred during the migration months. (d) Damage due to migrating birds during the past ten years has cost tens of millions of dollars.

The following data emphasizes the dangers of bird-aircraft collisions:

1. A raven weighing 450 grams, hits the windshield of a car moving at 80 km/hr with a force of 150 kilograms.
2. This same raven, colliding with a fighter aircraft flying at 800 km/hr hits it with a force of 15 tons.
3. A Black Kite weighing about 900 grams hits with a force of 22 tons.
4. A Griffon Vulture, weighing about 6 kilograms, hits with a force of about 50 tons.
5. A White Pelican, weighing about 10 kilograms, hits with a force of 100 tons.

Aircraft-bird collisions are an international problem. However in Israel, due to its unique geographical location, the problem is especially serious, despite the small size of the country. Hundreds of IAF aircraft in such a small airspace along with the millions of birds migrating through this same space for six months each year, have caused many

collisions. Until 1983, the IAF made no special effort to solve this problem.
In March, 1983, I contacted the Flight Safety Wing of the IAF for permission to use a Cessna aircraft to track high altitude migration routes. At the first meeting with the Air Force officers we were told of the serious damage done by migrating birds. As a result, we started a joint study by the Israel Air Force, the Society for the Protection of Nature in Israel (SPNI), and Tel Aviv University, which was done in the framework of my doctoral thesis. I planned to do research whose conclusions could be applied operationally in the Air Force exercises, in order to significantly decrease the probability of aircraft collisions with migrating birds. The Air Force commander had given flight safety top priority at that time.
Objectives of the study:
The objectives of this study were to find answers to the following questions: 1. Is the number of birds appearing each year and each season (spring and autumn) constant? 2. Is the time of appearance and length of the migration wave constant each year and each season? 3. Are the migration routes over Israel (horizontal plane) constant on a daily, seasonal and yearly scale? 4. Is there regularity in migration altitude (vertical plane) and velocity? 5. How do climatic and biological factors influence variations in this system? 6. Is it possible to predict variations in migration characteristics and implement these predictions in the Israel Air Force?

Methods

Five different data gathering methods were used for this research:

1. **Ground Observing Network.** A majority of studies have tracked migration with small numbers of observers at 2-3 key observation points. In this study, for the first time ever, ground observers were placed along a broad front: 25 observation points were placed across the country, along 75 kilometers from the Mediterranean coast up to the Rift Valley, during several migration seasons. More than 150 experienced birdwatchers logged about 224,000 observation hours. The system is still working continuously, to the present.
2. **Light Aircraft Tracking** - this method proved excellent for locating principal migration routes, their altitudes and counting flocks per time and distance units, and proved to be very efficient on "peak" migration days. Additional flights were carried out to confirm the radar distinction ability (see method 5). Twenty-nine flights totaling 83:40 hours were carried out.
3. **Motorized Glider** - This method enabled continuous flying, up to 11.5 hours, with the same flock, as well as exact mapping of the migration route, altitude, flock progress rate, climbing and gliding in thermals. One hundred and seventy three flights totaling about 720 hours were carried out. This was the first time motorized glider migration tracking was used in the Middle East. No study using a motorized glider to systematically follow migration flocks for such long periods of time had been done up to now, both in the number of flight hours and the number of tracking days.

4. **Unmanned Aircraft (Drones).** This method enabled tracking single flocks for about 150 kilometers with constant documentation of the flock by video camera. Nineteen flights were carried out. To the best of our knowledge, this is the first biological study ever to make use of this military instrument for research.
5. **Radar** - A surveillance radar at Ben Gurion International Airport (ASR-8) was permanently available during the migration seasons. This enabled constant tracking during all hours of the day. The cloud radar of the Shaham Company followed migration regularly only during one season. Its use was terminated due to technical problems. A total of 8125 radar tracking hours were carried out. This is the first time radar was used to follow soaring bird migration in the Middle East and in Israel specifically. The system is still working continuously to the present.

Most migration tracking research has been limited to one method, and only a minority combined two methods simultaneously, such as a combination of radar and ground observers (Evans & Lathbury 1973) or light aircraft and radar (Pennycuick, Alerstam & Larsson 1979). In our study, we have developed, for the first time, to the best of our knowledge, research based on a combination of five methods for data gathering from one migration system, with each method complementing, at least partially, the deficiencies of one of the others. At the same time this enabled confirmation of research methods by integrating the various methods. The radar could , for example take over from the motorized glider for a short period of time to enable refueling and rest, it could then direct the glider to the exact position of the flock it had left to continue tracking.

The statistical analysis in this research is based on nine autumn migration seasons for raptors and four for storks and pelicans. During spring migration raptors were followed in Eilat for six years and storks for four in the western Negev.

Results

Producing a Map of the Bird-Plagued Zones

From the reservoir of data which were collected and analyzed, we were able to draw a map of the Bird Plagued Zones (BPZ) delineating the routes taken by the major concentrations of birds. Fighter planes have been forbidden to use these routes at low altitudes, except for take-offs and landings. Research data revealed that the masses of soaring birds are concentrated, on most days, at altitudes up to 3000 feet AGL, and the permitted altitude for fighter planes was regulated accordingly. It was recommended that carrier planes fly at lower speeds within the limited areas.

Predicted times for the start and end of the migratory season are printed on the map. Various colors are used to show the areas where different varieties of birds appear on different dates, for instance: Large masses of storks migrate south along the Afro-Syrian Rift as early as August, while the great wave of birds of prey arrives only at the start of September, flying primarily along the parallel route to the west. The map also carries

detailed instructions for planning flights during the migration season and for dealing with any sort of collision with the birds.

Two separate maps were published, one for the spring migration season and one for the autumn (see Fig. 2) and the written procedures, known as the BPZ Regulations became part of the IAF's official codes. The maps are distinguished by high quality color print meant to stand out and attract the eye of every pilot when they are hung, according to orders, in the briefing rooms of every air squadron.

Marketing the Bird Issue and the BPZ and "Selling" Them to the IAF

During the course of our research, an elaborate program was introduced into the IAF to raise pilot consciousness about birds and the IAF's conflicts with them. A course of lectures accompanied by films and slides was delivered in all air squadrons and to other IAF personnel, such as radar units, who are involved in flight systems. The IAF also produced, in cooperation with the SPNI, a series of color posters on the subject along with calendars, stickers, explanatory pamphlets, and a video cassette series which was distributed to all flight squadrons during every migratory season. Thanks to this "marketing" program and the new army regulations, the bird issue has become an important part of IAF conciseness within an unexpectedly short time.

Establishing the Birdwatching Center at Ben-Gurion Airport

In order to establish a single center which could collect all relevant data regarding movement of birds from all the sources of information and to distribute this information in real time to all parties in the IAF who might need it, we established the Birdwatching Center in the control tower of Ben Gurion Airport. It is currently run 24 hours a day by an SPNI employee and biologist and by four IAF radar specialists. A direct, private telephone and fax line near the radar screen ensures that the information is relayed smoothly and quickly. Input comes from the network of ground observers, aircraft (motorized glider and civilian and military planes) control towers of IAF bases, and radar control units. The Birdwatching Center provides ongoing information about flocks of birds located by radar which were flying in close proximity to IAF air bases or the approaches to them. We also developed a procedure to calculate the speed of the migrating flocks to deliver near real time warning event to those Air Force bases which are out of the Ben Gurion radar system range. When huge flocks flew over shooting training areas, a real-time warning is given to the IAF control center to close the area in real time until the flock completely passed by. On days of heavy migration, warnings were also delivered to IAF radar control units to call off flights even outside the BPZ. Since some of the Air Force's largest bases are located in the center of the BPZ with a high number of landings and take-offs this real-time information was highly effective. Officers in the control towers thus had the opportunity to change the direction of landings and take-offs according to information about the birds' routes which was provided by the Birdwatching Center. On days with low migration, we permitted low

altitude flights in the BPZ, depending on the high reliability of radar to immediately signal any new flocks approaching.
Operation of the Birdwatching center is critical because, during each season, there are a few days with dramatic changes in wind direction and speed. These changes such as NW winds becoming southerly or SE push the flocks out of the BPZ. In such cases the Center provides immediate reports to warn the whole system of the changes in real time.
The Birdwatching Center begins its Real Time Warning System activity on August 1 for autumn migration and on March 1 for spring migration (in each case, two weeks before heavy migration is expected to begin). The activity ends on November 30 and May 30, two weeks after heavy migration usually ceases.
This procedure allows us to follow the migration from the moment it starts to build up in significant numbers and to provide warnings about the presence of smaller flocks flying through which do not necessitate putting the BPZ regulations into effect. The final two weeks of the Center's season give the IAF the opportunity to fly at low altitudes, with no limitation in the BPZ with the understanding that the Center will provide real-time warnings about small flocks which are still present and might cause problems.

Final Results

Since the BPZ regulations and Real-Time Warning System were put into effect, the number of air collisions with migrating birds has fallen dramatically. In the 17 years since we began the operation the IAF lost two aircraft due to collisions with migrating birds, and there was a reduction of 76% in severe air collisions, saving the IAF approximately 450 million US dollars since 1984.

From Local To Regional Activity

During the last few years the peace process has gained real momentum. Following the peace process in 1982 between Israel and Egypt, a peace agreement between Jordan and Israel was signed, relations with Turkey were significantly strengthened and a new era of close relations between the Air Forces was developed. The IAF as well as NATO and United States Air Forces train in Turkey leading us to the idea of expanding the local flight safety programs to a regional level. We believe that flight safety and birds, which know no political boundaries (as a migrating stork or eagle can cross in one day three to five counties in the Middle East) can be an effective tool to share our experience and improve relations between the pilots and people through the common interests of safer flights and the protection of birds. Several bi-lateral meetings between the different air forces in the last three years brought us together in April 1999 at the seminar to discuss how to develop a real time warning system in the Middle East. A few subjects are proposed to advance the potential cooperation between the Jordanian, Turkish, Israeli and US Air Forces (and hopefully the Egyptian Air Force as well as others in the future).

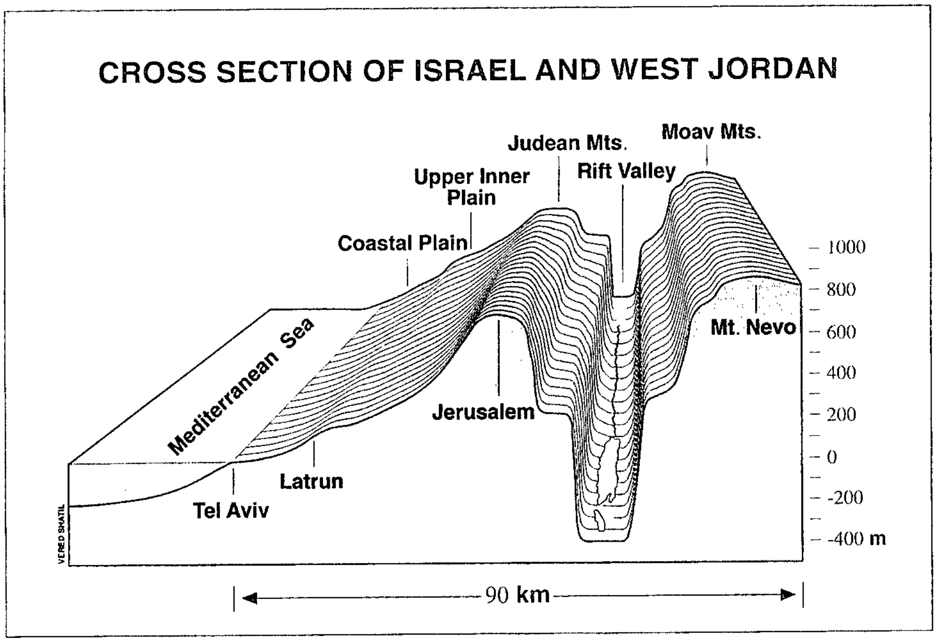


Figure 2: A cross section of Israel and Jordan that illustrates why the western migration axis that lies over the western slopes passes over the Armored Corps Memorial in Latrun and the parallel axis over the Jordan Valley. (Drawing: Vered Shatil)

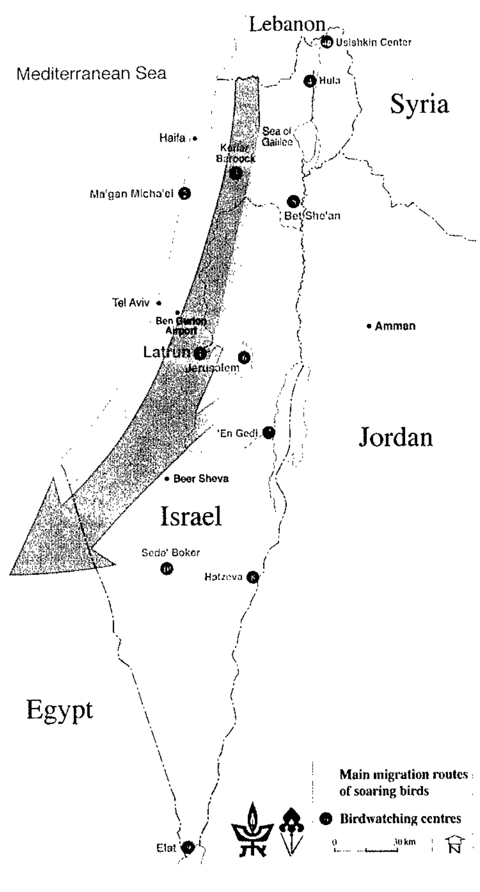


Figure 3: Schematic drawing of the autumn Bird Plagued Zones (BPZ) produced by the Israel Air Force, marking areas where fighter aircraft are forbidden to fly below 3000 feet AGL in the migration seasons. (Drawing: Vered Shatil)

Figure 4: *Awareness campaigns are most important as an integral part of educating pilots and decision makers in the air forces to protect both the aircraft and the birds. Above: This sticker promotes awareness in IAF fighter plane and helicopter squadrons to regulations which limit flying near raptor nesting sites (Drawing: Tuvia Kurtz) Below: A shoveler nature conservation stamp produced jointly by the SPNI, the Israeli Government Coins and Medals Coperation and the Unicover company in the US. The postage stamp was dedicated to the Spitfire flown by Israel's president Mr. Ezer Weizman during the War of Independence. The duck conservation stamp appeared on 24 September 1998 and the special seal of the philatelic service was produced especially for the celebration honoring the Jubillee of the IAF Radar Unit*

The International Center for the Study of Bird Migration at Latrun, Israel

As migration research in Israel intensified, in 1995 the SPNI and Tel Aviv University initiated the establishment of the International Center for the Study of Bird Migration at the Armored Corps Memorial in Latrun.

In the heart of Israel, at the foot of the Jerusalem Hills overlooking the Ayalon Valley and the Coastal Plain, midway between Tel Aviv and Jerusalem next the main highway (Route 1) and 18 km southeast of the Ben Gurion Airport lies Latrun.

The Latrun area is renowned since the days of the Bible in the adjacent Ayalon Valley, Joshua fought the famous battle during which "the sun stood still, and the moon stayed" (Joshua, 10:12) and many years later Judah Maccabee fought the Battle of Emaus nearby. It was also one of the most important crossroads in the Middle East, where the roads from Jaffa to Jerusalem and from Gaza to Ramallah and Damascus, met. Close to the site is one of the largest Crusader castles in the Middle East. The Israel Armored Corps has established a memorial at Latrun to honor the memory of the 4,862 Armored Corps soldiers who gave their lives in Israel's wars. The memorial includes a museum with an open-air exhibition of 150 tanks, one of the largest of its kind in the world. The site, with its unique history and convenient location attracts many visitors. In 1998 alone, about 400,000 people - families, soldiers, schoolchildren and tourists - visited the site. Latrun is located at the very heart of the western migration route, which lies along the foothills of the Judean and Samarian Mountains.

The board of the Armored Corps Memorial at Latrun have allocated Tel Aviv University and the SPNI an area of eight acres on the western side of the site for the establishment of the International Center for the study of Bird Migration. Tel Aviv University currently leads the research institute at the complex and will hopefully be joined in the future by other academic institutions so the center will become an inter-university project. An MRL-5 weather radar, purchased in Russia, was brought to Latrun in 1996 and is operated by Dr. Leonid Dinewitz, a Jewish Russian general, who immigrated to Israel from Moldavia.

A 200-seat auditorium and an interactive museum will be built at the site. Visitors will be able to hear, see and actively participate in exhibits illustrating the theme of migration, the joint research project with the IAF and how peaceful coexistence between migrating birds and aircraft was achieved.

A joint educational center for the Armored Corps Associations and the SPNI is now being build and will have 50 rooms, classrooms and a dining hall for students, soldiers and nature lovers from Israel and abroad.

The conceptual purpose of the project is to combine history - the Armored Corps Museum and the battles fought around Latrun in the past - with the future: bird migration, flight safety, environmental protection, eco-tourism and education.

A regional network of bird and weather radars

Radars were developed for military purposes in order to control air traffic and locate

aircraft. The greatest advantage of the radar is its ability to identify diurnal as well as nocturnal migration, and to follow migration at high altitudes beyond the scope of observers on the ground. Researchers previously used existing radar systems developed for five main goals. 1) Military use and air traffic control 2) Anti-aircraft fire system radars 3) Airport surveillance radars 4) Weather radars for predicting climate changes 5) marine radars.

Civilian air traffic, as well as military flights, have increased significantly during the last decades. Military air forces now fly at low altitudes during day and night, using fire zones in several countries. The cost of commercial and military aircraft has increased two fold during the last decades. Due to these reasons, the potential for damage caused by birds has increased drastically.

Over the past three decades a number of articles on migration research by radar have been published (Gauthreaux 1970, Richardson 1975, Kerlinger 1989, Bruderer & Liechti 1995, Buurma 1995, and others). Following several meetings of the International Birds Strike Committee (IBSC) it became necessary to produce a publication on the application of radar for bird migration research. Buurma and Bruderer (1990) produced a comprehensive booklet on this subject which summed up the problem very well, general aspects of bird detection by radar, different types of radars and their suitability for bird observation and operational use. We propose the development of a regional network to predict bird movement at the same level as has been achieved in weather prediction.

Networks predicting changes in weather have improved significantly in the last 20 years. The networks are based on weather radars, satellites and worldwide databases. The US government has invested $2.7 billion in a joint project of the Federal Aviation Administration (FAA), National Weather Services (NWS) and the Ministry of Defense in creating a network of 165 NEXDRAD radars (new generation Doppler radar) model WSR-88D, replacing the older model WSR-57 radars. The NEXRAD radars are located at airports and weather stations, covering the entire US.

Radar has proven to be an extremely effective operational tool for use warnings statements and short term forecasts. This is because, in part, it provides complete coverage of the volumetric area surrounding the radar out to 248 NM (460 km) and to an altitude of 60,000 ft (20 km) AGL at five minute intervals, three moments (reflectivity, mean velocity and velocity spectrum width) algorithm processing products totaling more than 75 displayable forms. In addition, the system is designed with considerable operational flexibility and capability. However, with this quantum leap in capability comes the necessity for effective management of system resources, careful product selection, and rapid recall time interpretations resulting in correct decisions and actions. Alden Electronics, Inc. has been selected by the NWS as a NEXRAD Information Dissemination Service (NIDS) provider. In conjunction with that service, Alden had developed the ALRAD II software, which provides the capability to access and display data from a network of NEXRAD Radars. Through Alden Electronics everyone can have complete access to the data.

Larkin & Quine (1988, 1989) studied the possibility of implementing bird recognition algorithms in the large S-band pulsed Doppler radars. The radars are equipped with a narrow beam and great power (1 megawatt) and sensitivity (90 dB dynamic range). Apart from the radar data acquisition subsystem it includes a radar products generation subsystem and a principle user processor subsystem. Digital NEXRAD weather data are automatically processed by large computer programs but in periods without severe weather the system has the optional capacity to offer considerable processing time to run special bird programs. It is thought that it has the option of bird information every 5-15 minutes. Calculations show that a single herring gull would theoretically be visible as a faint target at a distance of 450 km (but, of course, never will fly high enough to ascend above the radar horizon). Songbird echoes during migration often extend out to beyond 100 km.

The researchers expect to be able to devise algorithms allowing NEXRAD to automatically distinguish echo patterns of weather and birds according to: 1) the speed of the birds, 2) their appropriate migratory directions, 3) the time of day of their flying activities, 4) their relations to topography and 5) certain echo characteristics. The plans were to let NEXRAD radars report bird hazards with reference to large geographical areas and to estimate the degree of hazard in different altitudes over the entire USA.
Unfortunately, the involvement of the bird issue in the developing programs of NEXRAD system was stopped and the algorithms for birds detection did not receive the high priority they deserved. To the best of our knowledge the NEXRAD weather radars are a success story for weather usage, but the enormous potential for detecting bird movements is only now starting to be utilized by either the United States Air Force (USAF) or the FAA.
Since 1992, Prof. Gauthreaux has been following the migration recorded by 14 NEXRAD radars along the eastern coast of the USA, while also using moon watching, marine radar, and other direct visual means. Gauthreaux believes (Pers. Com.) that the data gathered by the continental network would be unmatchable in the detail that it provides (see pictures 3-4).
A daughter group producing NEXRAD radars was created in East Asia. 14 radars have already been ordered and there is no doubt that in the coming decade a wide network of NEXRAD radars will develop in East Asia.
Following the fatal air collision of an F-15 with three white storks on 10 August 1995 in the Negev Desert, Israel, in which both the pilot and the navigator were killed and the aircraft destroyed ($50 million damage), the IAF Chief of Staff is now investigating which radar to purchase, and a decision will be rendered by the beginning of the coming millennium.
We proposed that following the installation of the network of radars in Israel, a regional radar program can be developed with other Middle East countries (see figure 6).
We proposed to solve flight safety problems on a regional level, which will be much

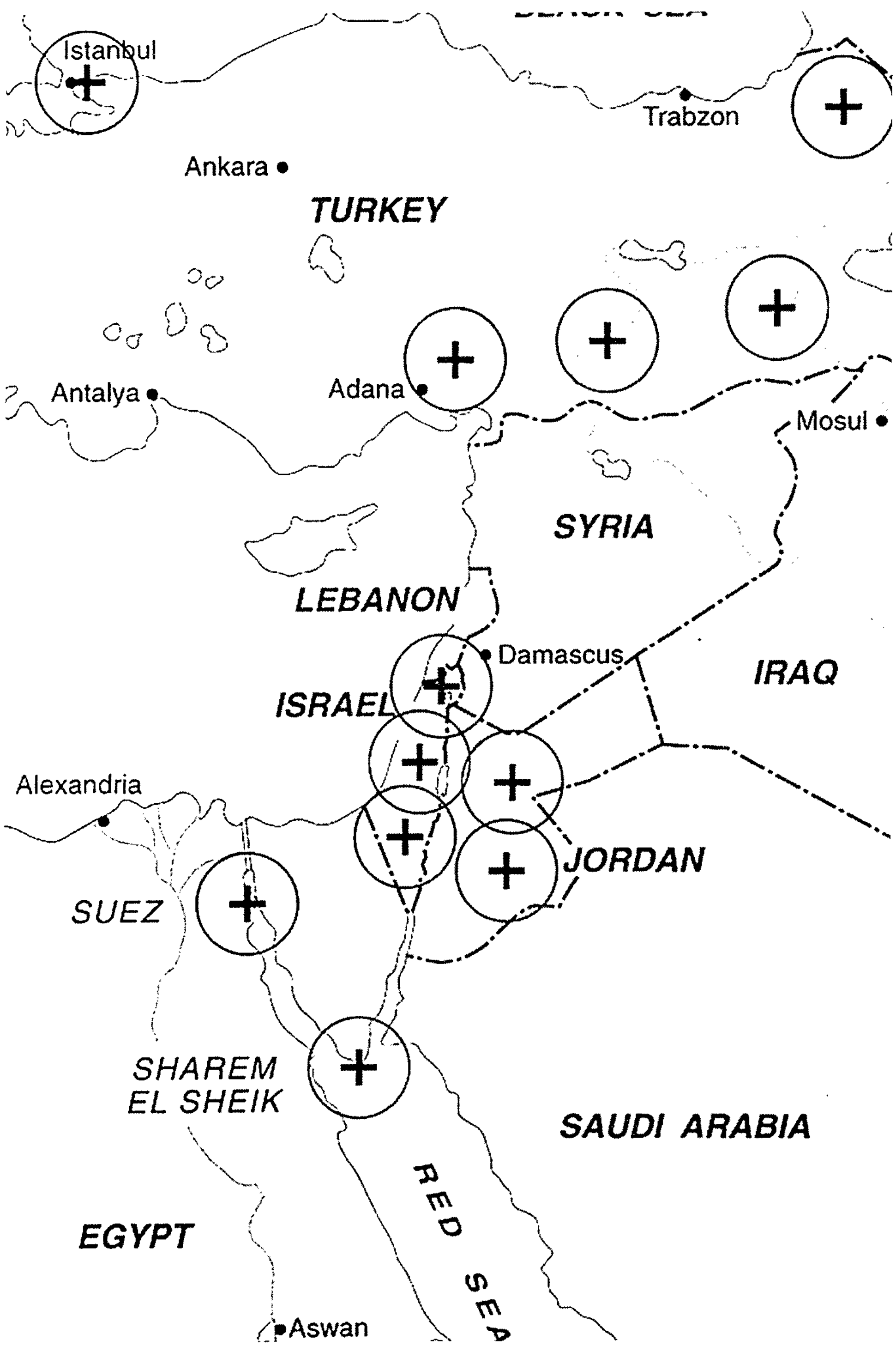
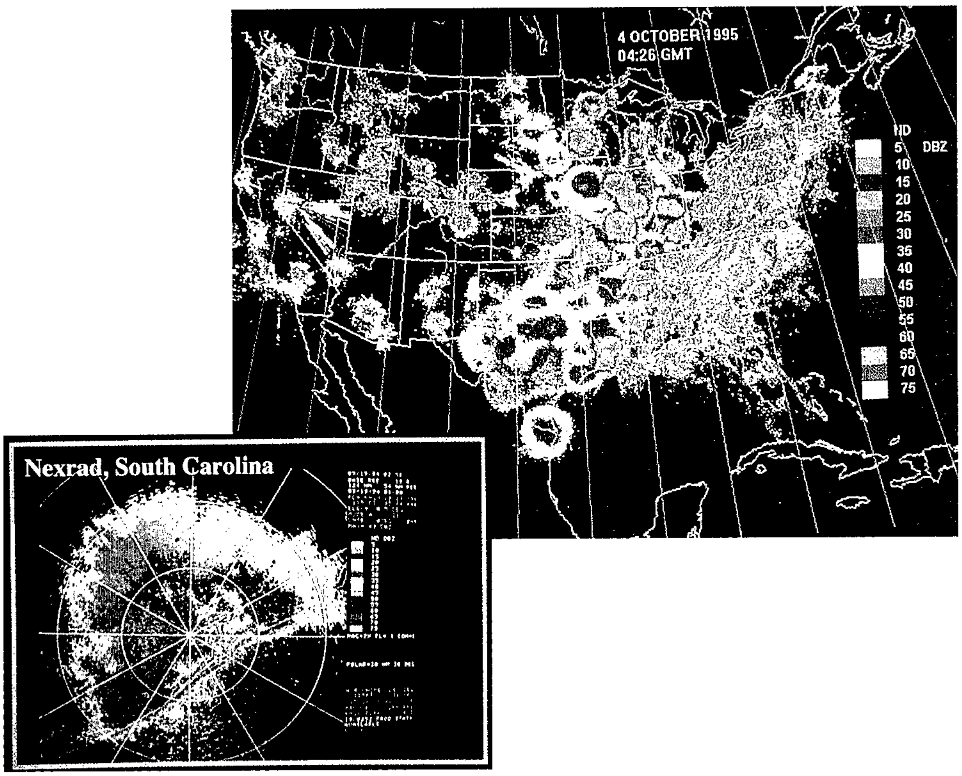
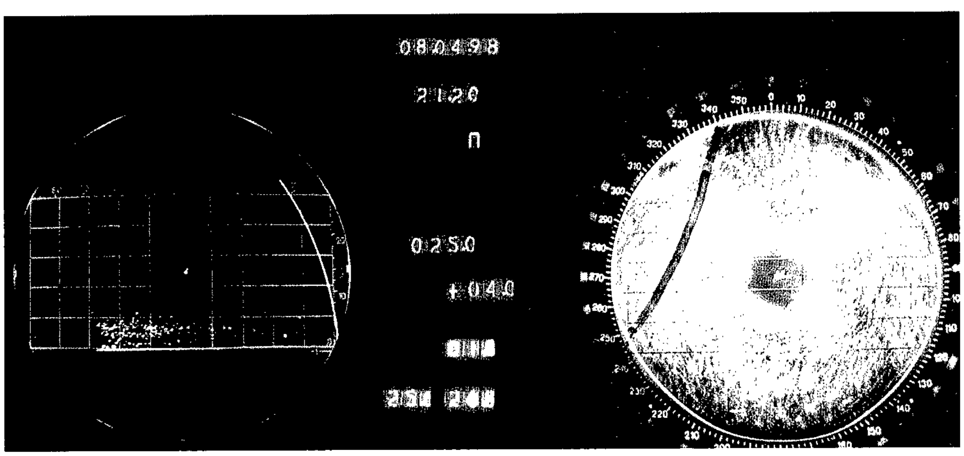


Figure 6: A schematic proposal for a radar network in the Middle East.



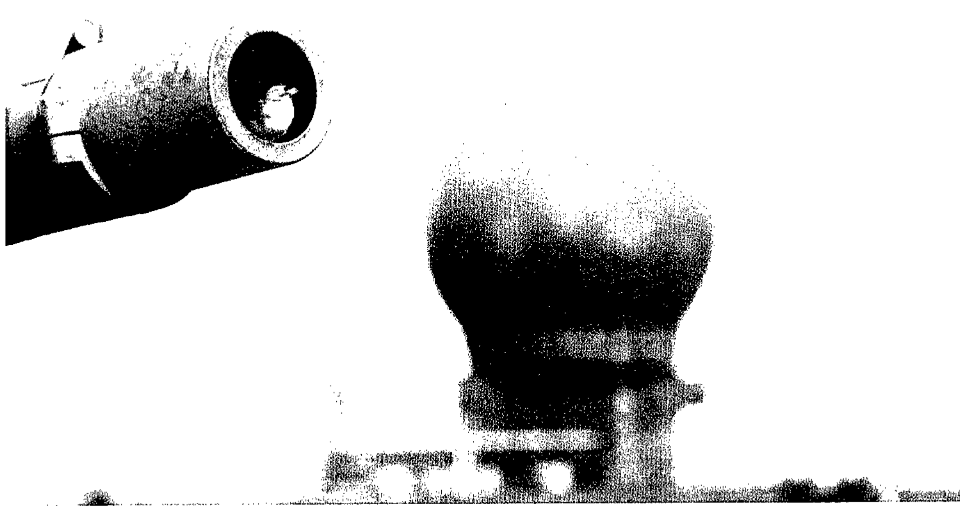
Pictures 3-4. *In the left photo, heavy migration (blue) of birds across the Gulf of Mexico in the early evening is seen as tracked by a NEXRAD radar. In the right photo, the national network of 165 NEXRAD radars in the USA. The compressed reflection of heavy migration follows a front on 4.10.95 at 04:26. (Photos: S.A. Gauthreaux Jr.)*

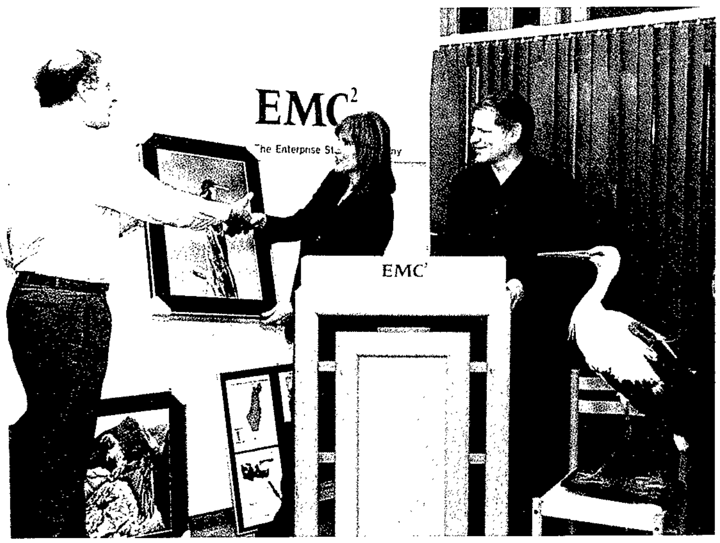
Pictures 5-6. *Massive night migration as seen on the MRL-5 radar at Latrun on 8 April 1998 at 2120h. On the upper right the entire area is covered by migrating bird flocks; in the center of the screen is Latrun, and the red line is the Mediterranean coast. On the upper left is a vertical section of the flocks on the right hand photo. On the RHI screen each square is 2.5x2.5 km. The major mass of migration is concentrated up to an altitude of about 2.5km. (Photo: Dr. L. Dinewitz)*



Pictures 7,8. *The Latrun memorial overlooks the Ayalon Valley where many battles were fought from the days of Joshua when the sun stood still. This sunset was photographed from the Russian bird radar on 24 November 1997 and brings to mind the verse from the Book of Joshua (10:12): "Sun, stand still upon Gibeon; and you, Moon, in the valley of Ayalon". (Upper and lower photos: Yossi Leshem)*

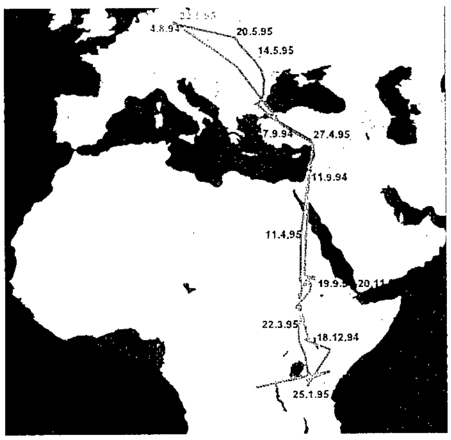
Picture 9. Above: *June 22, 1998. A team of senior pilots from the Royal Jordanian Air Force learning about our successes at Latrun and developing cooperative projects between both air forces.* ***Picture 10. Below:*** *"...and they shall beat their swords into plowshares and their spears into pruning hooks..." (Isaiah 2:4). A sparrow in a cannon muzzle of the Merkava Tank at Latrun, in the background the Russian bird radar. (photo: Andre Berthmann)*



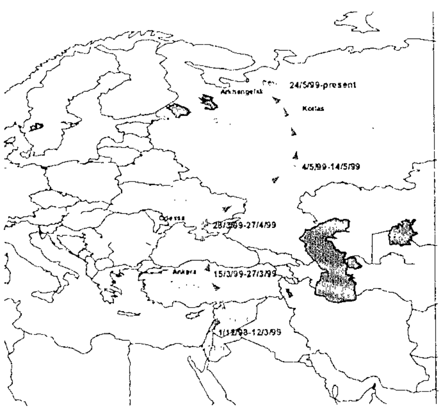


Left: *Moshe Yanai, EMC² Vice President, and his wife Racheli, at a ceremony in Tel Aviv, in which EMC², one of the world's leading enterprise storage companies, sponsored a section in their Tel Aviv branch, with rooms and computers, which operates as a data-base system on flight safety and research on bird-conflict issues (Photo: Adiv Gal).*

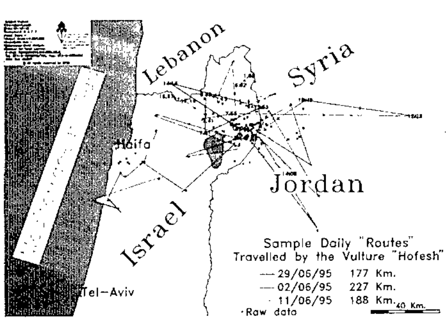
Figure 8. Below: *A schematic description of how the Argos Satellite System operates.*

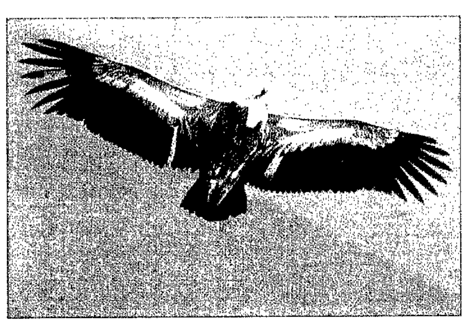


Left: *This is an example of the entire migration route of a white stork named Princess tracked by children through the Internet program "Migrating Birds Know No Boundaries" from April 1994 through May 1995. The Green route is the southbound migration from Europe and Africa during 1994 and the red route is for 1995, when the stork returned to the same nest.*
Right: *Attachment of satellite transmitter to the back of a stork. (Photo: Benaya Bin-Nun).*



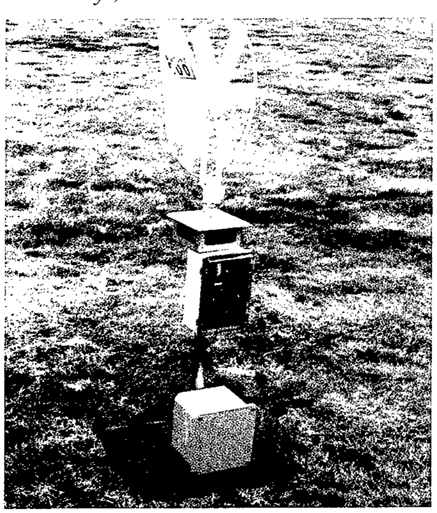
Common crane with attached satellite transmitter in the Hula Valley, northern Israel. The map shows the crane route from its wintering ground to its breeding site 6,500 km north of the Middle East. (Photo: Ephi Sharir)

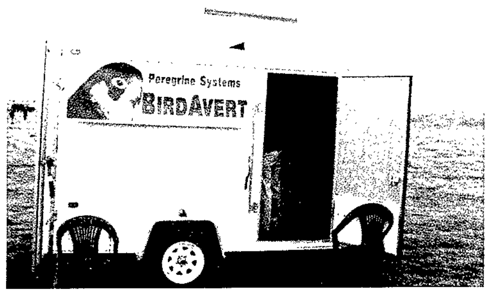


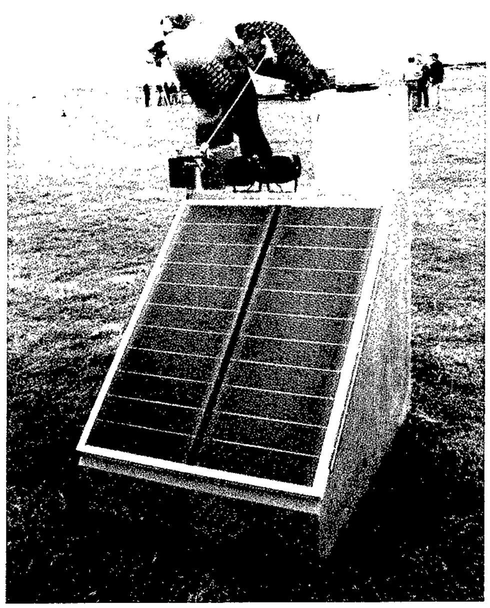


Right: *A Griffon Vulture in flight. Note the bleached flight feathers and the colored rings on its legs that allow it to be individually identified in the field. (Photo: Ofer Bahat).* ***On the left,*** *the route of the vulture flying over the Middle East in one month, over Lebanon, Syria, Jordan and Israel.*

Pictures 14-15. (right) *Mobile radar system with a peregrine model scaring system. The model flaps its wings activated by the radar (below).*
Picture 16. (above) *The very successful use of Border Collies in Florida, trained by Dr. Nicolas Carter to chase birds along the airstrips. The same technique is also used at Vancouver International Airport.*
Picture 17 (above right). *A highly mobile small 4x4 carrying a gas cannon, gives a bird control unit the ability to react quickly to landing flocks of birds.*
Picture 18. (below) *Stress calls of birds with ventilator to achieve a higher range (and charge the battery!!).*







more effective than local systems. This regional system (see figure 6) would allow for real-time warnings between countries; for example, during autumn migration Turkey will warn Jordan (and hopefully in the future Syria and Lebanon) will warn Israel of migrating flocks, and Israel will in turn warn Egypt. During the spring migration, the same system will operate in reverse: Egypt-Israel-Jordan-Turkey. We already know from our satellite research that migrating storks can start a day in Egypt, cross through Israel and Lebanon or Jordan, and end the day at roost in Syria. The detailed migratory research which has been carried out in Israel can be expanded to Jordan, Turkey and Egypt; this research involves motorized gliders, networks of birdwatchers, radars and drones. The results will help to establish a regional database and a regional real-time warning system, as well as a bird avoidance model (BAM). The network of bird radars will also serve as weather radars, an eco-tourism real-time data source providing information on where to watch the birds and as a very important tool for the formal education system.

An operational plan for development and cooperation regarding these concepts appears at the end of these proceedings as was decided by the participants of the seminar.

Following Soaring Bird Migration by Satellites

Joint German-Israeli research on bird migration has been conducted since 1994 and funded by the German Ministry for the Environment, Nature Conservation and Nuclear Safety. The project is a cooperative venture between the Max Planck Institute, Vogelwarte Radolfzell in Germany, Tel Aviv University and the SPNI in Israel. Research focuses on migrating white storks and uses satellite transmitters to follow the birds and track their migration routes.

In 1984, modern technology first made it practical to use satellites for tracking birds, with the development of transmitters small enough to be carried by a medium sized bird without interfering with its normal behavior and ability to fly. Every 90 minutes the location of the bird can be identified across the entire globe. Through Internet the data can be accepted everywhere almost in real-time and help advance the real-time system as a regional project. Ninety two storks were followed by satellite and we are now involved in a few more projects with migrating ospreys, wintering cranes and resident griffon vultures which are moving through the Middle East (see enclosed maps).

Bird aircraft conflicts in air bases

This is a very well investigated issue and many papers have been published in the bi-annual proceedings of the International Bird Strike Committee (IBSC) - formerly called the Bird Strike Committee Europe (BSCE). This subject which concerns all air forces is also discussed in one paper in these proceedings (Shy et.al.). We are showing a few pictures exposing some new techniques are now being considered all over the world.

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The Royal Netherlands Air Force: Two Decades Of Bird Strike Prevention "En Route"

Luit S. Buurma
RNLAF, Air Staff, P.O. Box 20703,
The Hague, 2500 ES, Netherlands

Absrract

In 1979 the Royal Netherlands Air Force introduced the first electronic bird migration warning system (KIEVIT), exploiting the raw video of its air defence radars. The rationale behind this operational system, which was further improved in 1989 (ROBIN1) and 1997 (ROBIN2), is that with a limited number of flying restrictions the majority of "en route" bird strikes can be avoided. This is possible thanks to the clustered occurrence in time and space (in our case especially altitude) of migrating birds. However, avoiding peak bird densities implies the decision to accept the risk of moderate and lower bird densities. Furthermore, assessing the critical risk level has to be done preferably in close co-operation with NATO allies where training area and program overlap. Therefore, we took the initiative to set up a communal bird strike database according to a format ratified within the Standard NATO Agreement that also regulates the format of birdtams. This military database, called EURBASE, is aimed to analyse the costs and nature of the bird strike problem, to provide tools for a cost/benefit judgement of prevention measures and to monitor their effect. Progress and complications will be discussed. It is proposed to develop the bird strike analysis further according to two separate strategies: a quantatative approach based on full incident reporting and flying hours, and a qualitative, more casuistic approach oriented towards extended description and analysis of serious bird strikes. While the first approach remains semi-confidential in order to promote the sharing of operational experiences, the second approach should be fully open (Internet!) in order to collect as much as possible details on conditions, to provoke opinions and to share lessons learned.

Introduction

Holland has a long history of bird strike prevention. It started in the Fifties when several jet engine fighter aircraft crashed due to bird strikes. Well-known biologists like professor Niko Tinbergen and professor Karel Voous succeeded in convincing the Dutch government to cope with the problem following a scientific approach. When the Canadians, through NATO, came with an initiative to measure bird migration densities

by means of radar, the RNLAF directly joined this program by introducing in 1964 a warning system at its 23-cm radarsystem near Den Helder by means of polaroid time exposure photography. Bird control by Goshawks at Leeuwarden airbase was another program at that time.

The first ten years of bird strike prevention had an experimental character. During the seventies this approach evolved into a more regulated way of working, with the introduction of bird control units at all airbases and the development of an operational electronic bird echo counting system at the new 10-cm stacked beam air defence radar near Wier in the NW of The Netherlands (review in Buurma 1995, Israel Journal of Zoology, Vol. 41, pp. 221-236). In 1995 the RNLAF started again with an evaluation of her bird control program. This initiative got a strong extra impulse due to the initial role of a flock of Starlings in the fatal crash of a Belgian Hercules C-130 at Eindhoven AFB on 15 July 1996. As a result not only the local bird control was reviewed and reorganised, also the detection, understanding and modelling of bird migration and bird movements above and around airports was reconsidered.

"En route" bird strike prevention is the subject of this presentation. This paper will briefly describe some features of and the rationale behind our present bird strike prevention program by means of (semi-)automatic bird detection at long range surveillance radar, which started twenty years ago with system KIEVIT. This electronic bird counting device was improved in 1989 (ROBIN 1) and in 1997 (ROBIN 2) following the increasing possibilities of computer hard- and software. Now we are discussing long term plans with respect of refined 3-D bird detection by means of dedicated bird radars and the modelling and prediction of bird movements.

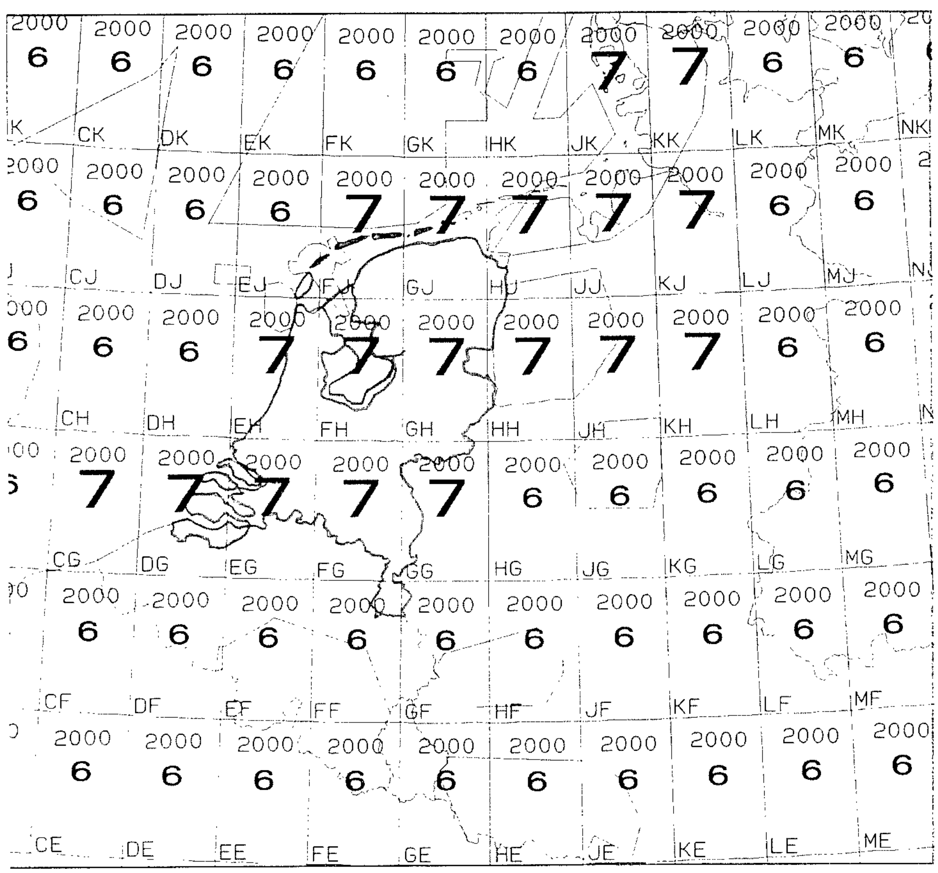
Bird warning systems

For many years the air forces of Denmark, Germany, Belgium, and Holland warn each other for waves of heavy broad front bird migration as registered by long range surveillance radars. The idea is that with a limited amount of flight restrictions most of the bird strikes during low level missions can be avoided. The bird density is expressed in an exponential zero to eight scale. The maximum value eight corresponds to very intense bird migration only observed during a few days each season and often causing saturation of the radar screen. Flight restrictions are usually imposed at bird intensity seven and eight. They are valid below the altitude level indicated in bird messages (so-called 'birdtams', bird notices to airman). The RNLAF integrates its own radar information with the information received by telex from the neighbouring countries into one integrated 'georef' map (figure 1). It is released each morning and is repeated every two hours in case the bird activity is scaled at five or more.

How do we assess bird migration intensity by radar? Figure 2 gives an example of a time accumulated radar image with a fairly massive daytime bird migration. The computer generated 'time photo' (of 10 minutes radar image) shows numerous short streaks across the screen caused by birds. A few dotted lines near Amsterdam are produced

GEINTEGREERD VOGELTREKBERICHT
23-04-97, 07.00Z tot 09.00Z, nr. 2

Uitgegeven door DOP/AOO, Sectie Natuurtechniek en Ecologisch Beheer, telefoon: 070-3492350



LEGENDA: 7, 8: Restrictie
5, 6: Waarschuwing
2000: Hoogte (ft) tot waarop de vogeltrek geldig is
-- : Vogeltrek < 5
?? : Vogeltrek onbekend

Figure 1

Integrated Bird Migration Message. Bold figures per georef indicate the bird migration intensity at an exponential 0-8
scale. Values 7 and 8 imply flying restrictions below the altitude in ft, also indicated in each georef. Values 5 and 6 imply a warning.

by aircraft, while the blue solid echo at the right edge represents a rainshower. The contours of The Netherlands are shown in white. Colors indicate the echo strength from weak (red) through yellow and green to blue (strong). This bird image illustrates the so-called broad-front migration from NE towards SW, typical for the autumn. The birds form a very uniform 'blanket' over the sea and the Dutch inland areas. As the echoes do not reach the far periphery of the image, the birds do not fly at maximum altitude, especially not over land. Nevertheless, the uniformity indicates that this bird density can be extrapolated somewhat outside the radar range. The fact that the bird echoes are clearly visible individually indicates that most birds fly in flocks.

When the birds fly in higher densities than in figure 2, the radar screen may become saturated by bird reflections. This results in blue images such as figure 3 (left), also collected during heavy diurnal autumn migration. This image was taken at the lowest radar beam (the radar has twelve beams above each other). Directly after this image we took a similar "time exposure" image of the second radar beam (figure 3 - right). By comparing this image with the vertical coverage diagram in figure 4 it can be concluded that the birds, because they are visible up to 60 km from the radar, were flying above the North Sea up to an altitude of 1500 meters. When arriving above the chain of islands along the Dutch North coast, all the migrants descended while turning right and following the Wadden Islands. Many of the birds (probably Turdus species) must have landed, causing a so-called "fall".

In order to analyse in detail the bird densities and movements, the Physics and Electronics Laboratory TNO in The Hague developed a dedicated bird video extractor called ROBIN (radar observation of bird intensity). The present second version of this special hard- and software configuration enables us to zoom in on the radar image and to use the highest resolution in order to extract bird echoes. This extraction is done by comparing almost real-time the images of 10 successive rotations of the radar antenna while covering up to one quarter of the whole display. Figure 5 gives a representation of the SW quadrant of the image of the lowest radar beam, directly after the registration of the images in figure 3. One can nicely see how the birds that fly at fairly low altitude (up to 300 meters) roughly follow the major contours of the Dutch landscape viz. the west coast of the province of Friesland, the Afsluitdijk, the new polders and the west coast of Texel and the province of North Holland.

ROBIN can handle even higher bird densities as is shown in figure 6 taken during the start of a heavy nocturnal migratory movement. Most probably almost all echoes were caused by solitary flying songbirds, The symbols indicate size, speeds and track directions. For further examples and discussion of both operational and scientific applications I refer to Buurma 1995.

Rationale

The rationale behind the bird warnings is that with a limited number of flying restrictions

the majority of "en route" bird strikes can be avoided. This is possible thanks to the clustered occurrence in time and space of migrating birds. Figure 7 gives a indication of the number of flying restrictions during the year 1996. As in most other years the operational impact of the bird warnings was limited to spring and autumn. In fact the impact was even less than figure 7 suggests, because almost always the low level flying program was only hampered during a small number of hours, mostly during the morning. Sometimes a whole exercise had to be postponed, but more often the damage to operations is small, especially when the end of the flight restriction could be predicted, which was often the case as the migration waves have a typical sequence. Figure 8 shows the operational impact over the last decade in the number of days (top) and the number of hours (bottom) during which at least one georef contained a warning (bird intensity 5 or 6) or a flying restriction (bird intensity 7 or 8). Not only in time but also geographically the hindrance of our bird warning system to operations is limited as shown in figure 9. The percentage hours per part of the day with restrictions (A,C,E) or warnings (B,D,F) is indicated per georef. It becomes clear that the coastal zone and the lowlands have the most intense bird movements.

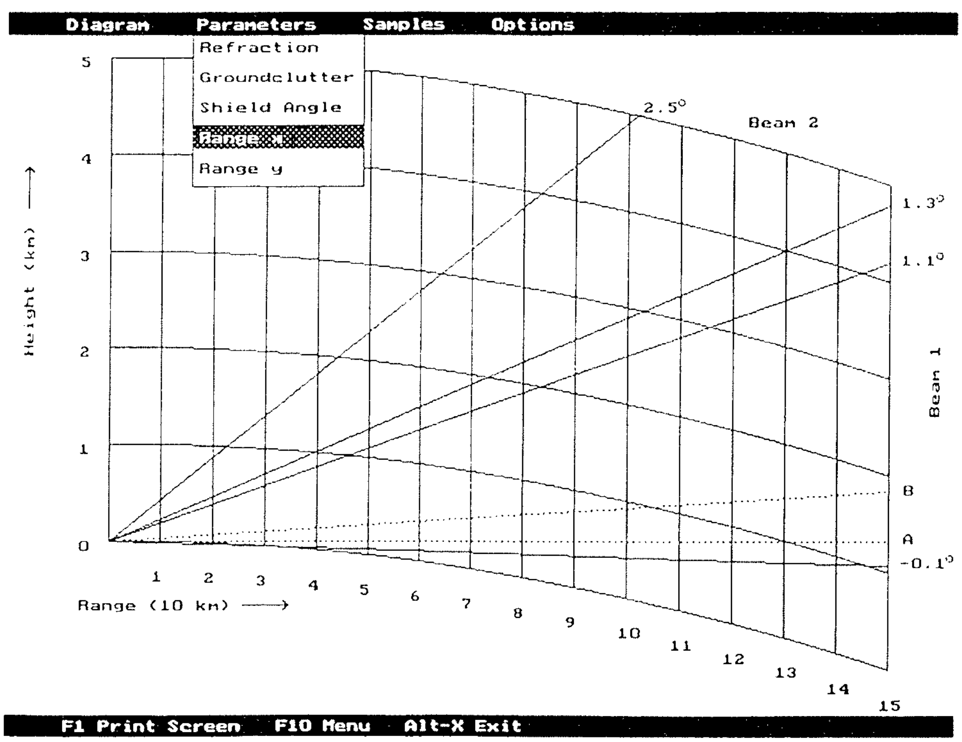


Figure 4: *Vertical coverage diagram program showing altitude against distance for straight lines representing radar radiation. The elevation of the lower and upper side of the two lowest beams is indicated to the right. The visual horizon is given by A. The program can adapt the vertical coverage of both beams to deviating refraction (normal factor = 1.33). When the radar horizon is shielded by hills, the lack of coverage can be indicated (e.g. B).*

The future

So far, the aviation world does not know of operational information systems that provide predictions about where and when to expect flying birds, including their altitudes and densities. What does exist are maps on the one hand and, as described above, in a few countries, ad-hoc radar warning systems on the other. What is missing are bird avoidance models mixing biological reference data, meteorological parameters and actual radar measurements of birds in flight. This is very curious, given the potential value of such systems and the enormous amount of ornithological field data currently available in several countries. For instance in Holland there are tens of thousands of amateur bird watchers, organised in several hundred local clubs, who are involved in several nation-wide and even international census projects. These projects are initiated, supported and analysed by professional biologists and institutions. The results are also exploited professionally by local, regional and national governmental bodies, the application being mostly spatial planning and nature management.
I can think of three reasons why systematic bird counts are not yet used for aviation safety purposes:
Firstly, aviation authorities have not yet realised that they can indeed profit from a spatiotemporal bird information system. Maybe there is a certain reluctancy to introduce such "soft" information.
This brings us to the second reason: there might be a cultural gap between the green world of naturalists and the hightech world of aviation. This gap blocks information exchange and fruitful cooperation.
But most important, in my opinion, is the third option: bird flying activity is still very much a terra incognito. The majority of bird movements remains hidden from the eye or occurs at a too large scale. Many birds migrate at night and/or at high altitudes. One would expect that three decades of radarornithological work should have resolved that problem. However, this did not happen. On the contrary, a lot of the radar work raised more questions than it provided answers. Only recently we started to understand that radar gives a very distorted picture of the realities of bird flight. Dutch attempts to consider radar and field observations indicated that they both detect only a part of the phenomena and that often there is a significant gap between the visual range upward and the radar reach downward. To make things worse: a lot of bird flying activity occurs in this altitude band as is indicated by the bird strikes (figure 10)!

Once we start to understand the problems, we also have the clues to solve them. My statement of today is that the time is ripe to stimulate the nature conservation oriented field observers and aviation people having access to radar equipment to join forces. Our modern society appreciates both human mobility provided via aviation as well as the care for a bird rich environment. Each contribution that helps to avoid further clashes between these two ambitions should be most welcome!

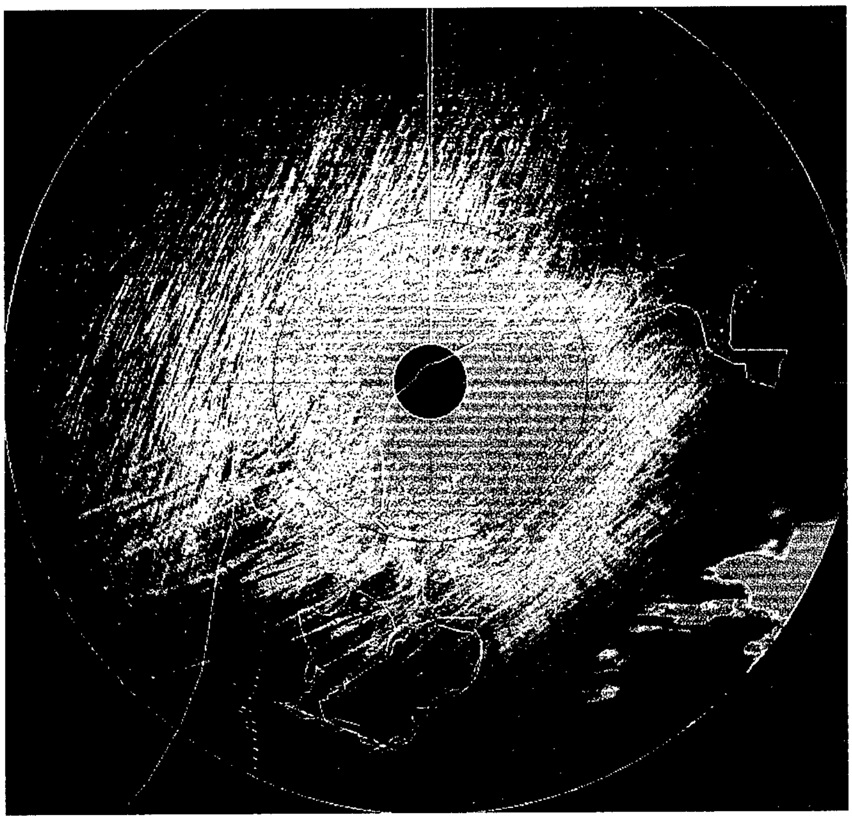


Figure 2: *Digital "time exposure photo" of 10 minutes of the radar image of the lowest beam of the stacked beam RNLAF air defence radar in the NW of The Netherlands. The orange and yellow stripes represent SSW bird movements across the North Sea and SW bird movements across land. Green and blue colors indicate saturation of bird echoes, ground clutter and a rain cloud above the border with Germany. Stippled lines near Amsterdam represent airliners towards or from Schiphol airport.*

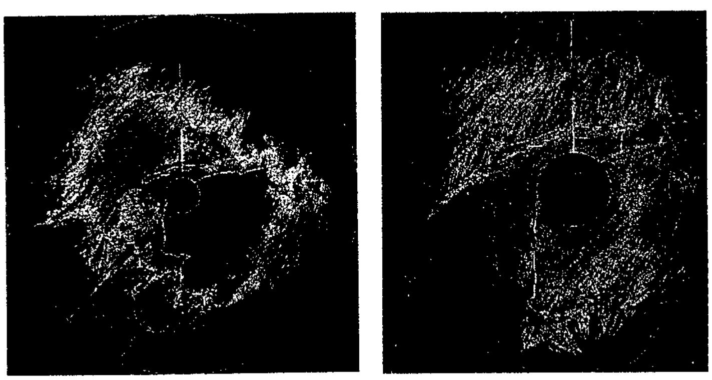


Figure 3 *Left: A similar ten minutes accumulation image as in figure 2 showing dense diurnal migration over the North Sea arriving in The Netherlands, as seen by the lowest radar beam on 20 October 1997 (08.10-8.20 local time)*

Right: The same migration wave seen by the second beam, ten minutes later (see text).

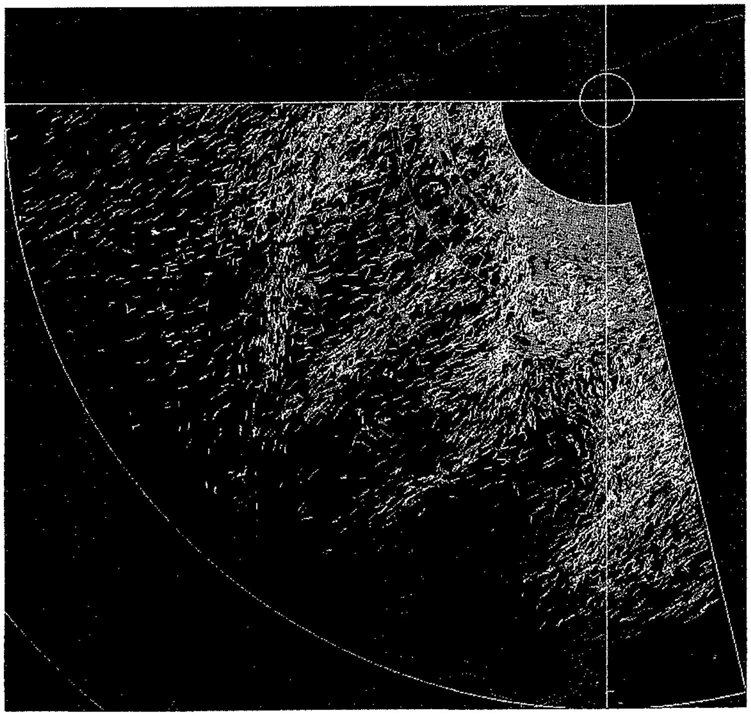


Figure 5 *Motion analysis by ROBIN2 at the SW quadrant of the lowest radar beam during 10 successive antenna rotations, a few minutes after the images of figure 3. All white traces represent the track of a single bird echo.*

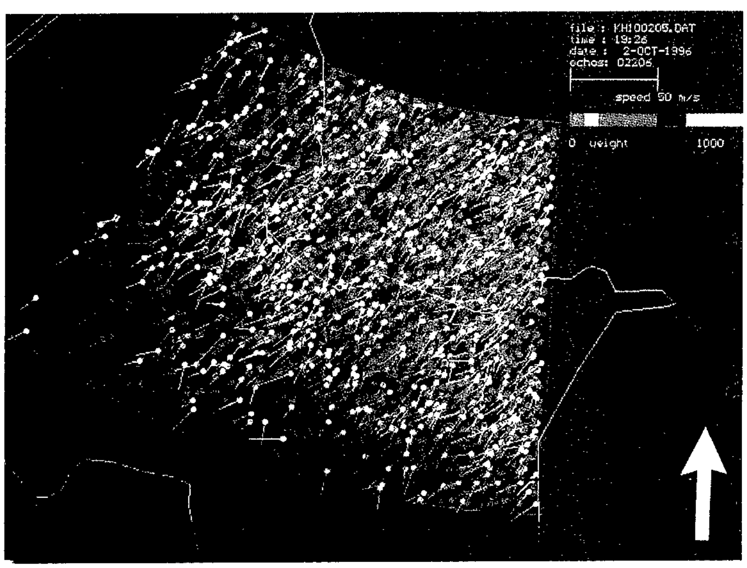


Figure 6*: Bird echo extraction over ten antenna rotations at highest radar resolution in a window around the SW corner of the province of Friesland (Gaasterland) and parts of Lake IJssel. Colors indicate the mass of each bird(flock). Length and direction of vectors indicate groundspeed and track direction. The sample illustrates the start of a very dense nocturnal bird migration on 2/10/96.*

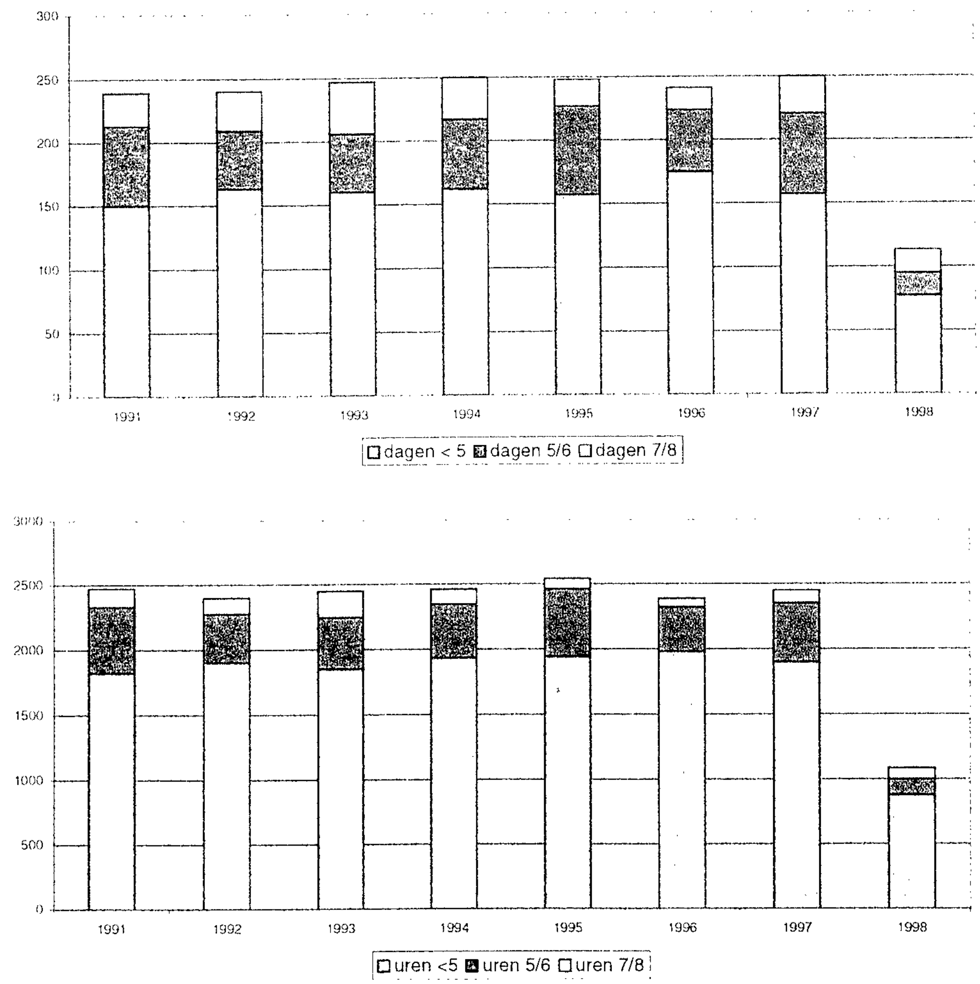


Figure 8
Top: Absolute distribution of the number of days (dagen) per bird migration intensity over the years 1991-1998 (1998 up to and including 24 June)

Bottom: The same but now in hours (uren)

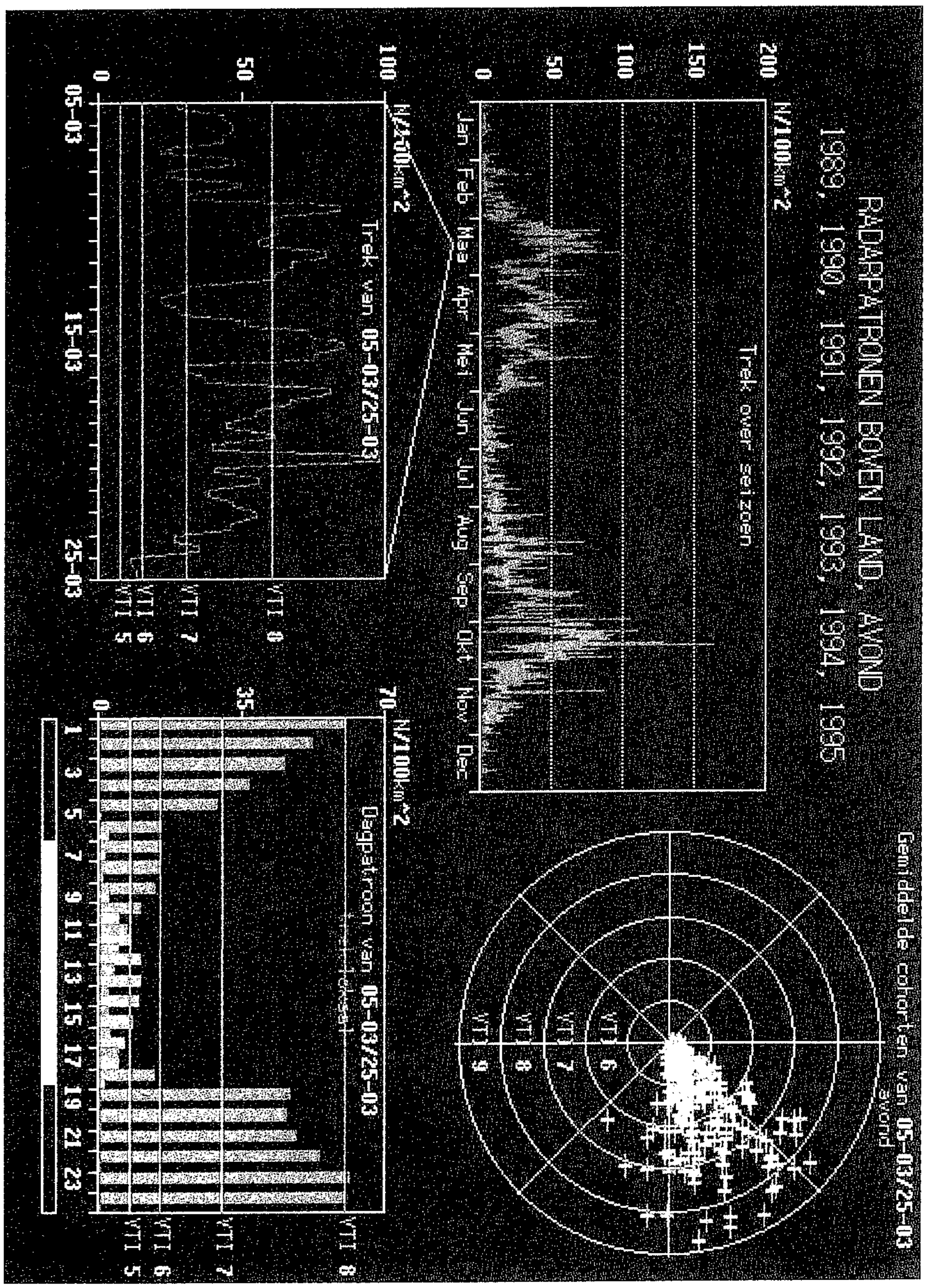


Figure 12: *Samples from the bird migration database based on bird echo counts from the long range surveillance radar in the NW of The Netherlands. The top left graph is a year round summary of average densities during nocturnal migration over land (1989-1995). The bottom left figure zooms in at the period 5-25 March (1989-1995) and adds the warning/restriction thresholds according to the 0-8 scale (VTI). In the bottom right figure the same data plus the diurnal data are averaged over 24 hours (in green local i.e.non migratory movements). The top right figure presents the average track direction of the nocturnal migration waves during 5-25 March, 1989-1995.*

GIS applications

As birds often start and end their flights in bird concentration areas, a first step to understand their flyways is to map the major refugia of the problem species. This obvious approach neglects, of course, those birds that are evenly spread across the countryside. But one should start somewhere, and it is a given fact that one cannot take into account each single bird. So, twenty years ago the Dutch Civil Aviation Authority ordered the development of a simple map for their Aeronautical Aviation Publication under the title 'Bird Sanctuaries and Bird Strike Risk' (figuur 11). The map features 52 important bird areas where pilots are advised to fly over 1000 ft., for their own sake and in order to reduce disturbance to the birds.

This map is not up-to-date anymore and it hardly takes into account the seasonal changes in the bird distribution. More important: it does not reflect the real 'bird meat underground' necessary for the reconstruction of regional and national bird flyways. One could argue that such a realistic 'bird meat map' would not work for aviation purposes because the lower half of The Netherlands would appear as one big bird area. In low resolution maps this could be true. In fact, twenty years ago this was the reason that Holland was divided in two bird strike risk zones: high risk in the west and moderate risk in the east. The division fitted an international map designed at the same time.

In the meantime, however, we learned that mapping efforts on the basis of recent bird censuses could result in much higher resolution. Moreover, we realized that such a resolution could make sense for flight safety. For instance, it is obvious from the local bird strikes at Schiphol Airport that our major airport is located relatively safely between dense bird flight lines through the IJsselmeer area as well as around the North Sea coast. If we allocate new airfield capacity outside Schiphol, for instance on the Maasvlakte, in the Markerwaard or at a new artificial island in the North Sea, it is very obvious that a much more detailed mapping effort is needed.

Given the currently available ornithological knowledge, the mapping process should be computer based as an application of a Geographical Information System. This would not only provide unlimited space for seasonal and even diurnal variations in bird distribution. It would also open facilities for creating zones around and between "bird hot-spots" indicating daily feeding and roosting flights. Ultimately, the electronic calendar/mapping system could be extended with overlays containing migrational flyways.

A first step in this direction has been taken by the Central Science Lab of the British Ministry of Agriculture, Fisheries and Food. They created a database of 800 bird hot-spots behind a scanned copy of the RAF's low-flying map which also shows air corridors, no-go areas and other low-level flying hazards. Bird concentrations appear as red dots on the screen of a high performance PC after the user has selected global parameters in combination: month, time of day (dawn, day, dusk, night) height (100, 250, 500,

1000 feet or all heights) and hazard level (high, medium, low or all). Only those sites that are hazardous at the chosen setting will be displayed on the screen; e.g. gull roosts will only be displayed during the winter months, tern colonies will only be displayed when the height is set to 100 ft or all. Clicking on a site brings up a dialogue box giving further details. This bird strike hazard GIS is now operationally being tested at an RAF squadron.

As the user is not overloaded with irrelevant information, the system seems pretty ideal for flight planning purposes. But also important is the unlimited growth potential, since the key is geographical coordinates and most of the GIS (Arcview) functionality with respect to zones etc is not yet exploited.
Such sophisticated steps will be possible as soon as more descriptive information on flying behaviour of the birds becomes available.

Towards integration of field and radar data

The use of long range surveillance radar has evident advantages: as far as high altitude movements are concerned the data are large scale and continuously available day and night. An impression of the type of summary data that can be collected as a reference source is illustrated in figure 12. In principle, these radar data provide a firm basis for the calculation of the amount of 'bird meat per cubic kilometer' and thus the bird strike risk. However, two crucial aspects are missing which limit the use for flight safety purposes: information on flying heights and on the identity of the birds.

As I already indicated in figure 10, most bird flying activity occurs in the lowest air layer, especially during the daytime. The radar is only scanning the upper parts of these bird movements. Most of it remains undetectable behind the radar horizon or between ground clutter, the reflection of objects on the ground. As a result we get a skewed picture of what is really happening and this seriously hampers interpretation and prediction. We have to conclude that the information of the long range surveillance radar and what we see in the field are, at the very best, complementary. Mostly, there is a gap. And as the big radar only provides echoes without bird identity, we cannot simply connect the bird movement patterns in the lowest air layer, as seen by field observers, with those higher up, which are very often totally different.

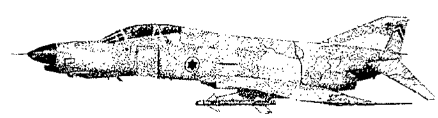
The gap between the bottom-up approach from visual studies in the field and the top-down interpretation of radar material must be bridged. This is not easy and can only be achieved by a series of special studies with registration techniques intermediate in scale. Currently the RNLAF Air Staff has started to study the feasibility of such a program, to be set up in close cooperation with several institutions also interested in bird densities in the air, not only in relation to the planning of new aviation infrastructure but also in relation to the construction of large scale wind turbine parks.

We started to use a mobile tracking radar for this purpose. Some experiments in the past showed that our Flycatcher radar was a good choice provided the radar was optimised

and adapted for bird observation. This was realized last year and this year we started a 3-D study of bird movements along the Dutch west coast. With the search beam of the Flycatcher single birds of Starling size can be detected in side view up to 7 km. By using the track antenna as a scanner in the vertical and in the horizontal plane we can measure the spatial distribution of birds quantitatively up to its ceiling of approximately 4 km. More important, we can track single birds and flocks as low as approximately 30 meters. This tracking facility goes along with TV identification in daylight or infrared at night. With respect to zones, etc. is not yet exploited.
Such sophisticated steps will be possible as soon as more descriptive information on the flying behaviour of the birds becomes available.

In combination with visual observers at ground level and the big radar as a high altitude reference, the Flycatcher bird radar could be used to analyse in three dimensions the rate at which birds accumulate around coast lines and other topographical borders under varying wind conditions. Further, the patterns and altitudes of feeding and roosting flights of gulls, geese, ducks, waders, and starlings could be mapped. Also the use of thermals by several bird species in different landscapes needs to be measured. A special air force priority is the 3-D modeling of mass bird movements in tidal areas such as the RNLAF shooting range at Vlieland. Also the bird activity in the control zone of existing and future airports could be evaluated.

Future Flycatcher studies will not only provide descriptive information of local value. They also will give birth to more general insight into the relations between bird flight, landscape and weather. The biological understanding of the spatial behaviour of birds will, for the short term, help to set up an international bird hazard GIS. For the longer term, this GIS will provide the basis for a more dynamic and predictive Bird Avoidance Model, using meteorological parameters. Actual bird movement measurements will remain necessary, but the sample size can be reduced the more we succeed in classifying and predicting bird movements.



Bird Flight Forecast and Information System

Harlan D. Shannon[a], William S. Seegar[b], George S. Young[c], Mark R. Fuller[d], Michael A. Yates[e] and M. Blake Henke[f]

[a] Center for Conservation Research and Technology, University of Maryland Baltimore County, Baltimore, MD 21250,USA,
[b] Edgewood Research, Development, and Engineering Center, Aberdeen Proving Ground, MD 21010, USA,
[c] Department of Meteorology, Pennsylvania State University, University Park, PA 16802, USA,
[d] U.S. National Biological Service, Raptor Research and Technical Assistance Center, Boise, ID 83705,USA,
[e]Boise State University, Boise, ID 83725, [f] Center for Conservation Research and Technology, University of Maryland Baltimore County, Baltimore, MD 21250 USA

Abstarct

The times and altitudes of avian soaring flight are often influenced by changes in thermal depth and intensity. Given these relationships, forecasts of these meteorological variables can be used to predict changes in the horizontal and vertical extent of the soaring bird strike hazard to aircraft. A boundary layer forecast model has been developed to predict such flight. The accuracy of this model was examined by comparing American White Pelican flight times and altitudes to hourly and daily changes in thermal depth and intensity. This model predicted 89% of pelican flight altitudes in the Fallon, NV area. Results indicate that white pelicans commuting between their foraging and breeding sites daily confine 72% of their flight between 0.2 and 0.7 thermal depth. In contrast, non-commuting pelicans were found to confine 80% of their flight between the ground and 0.4 thermal depth. These data illustrate the potential value of bird flight forecast models in reducing the bird strike hazard to aircraft. By combining bird abundance and distribution information with bird flight time and altitude forecasts, the expected horizontal and vertical extent of the bird strike hazard to aircraft can be identified approximately 36 hours before such conditions develop.

Introduction

Several methods have been developed to diagnose the extent of the bird strike hazard to aircraft. Examples of these methods include the implementation of wildlife monitoring programs, bird avoidance models, and radar surveillance techniques. Although these methods are effective in illustrating the current or historical avian threat

to aircraft, all of these methods are incapable of predicting changes in this threat beyond the limited skill of a track-persistence forecast. This paper describes the development of a forecast model that predicts changes in the times and altitudes of avian flight based upon the physical and dynamical processes that govern this flight. The goal of this research is to develop a comprehensive bird flight forecast and information system that combines the aforementioned diagnostic and forecast techniques to reduce the bird strike hazard to aircraft.

Model Theory and Development

Numerous studies have examined the relationships between bird abundance, distribution and flight patterns and such variables as habitat, geography, weather and climate. For example, DeFusco (1994) correlated geographical, meteorological, and physiographical variables with the distribution and abundance of Turkey Vultures in the United States. Kerlinger (1989) has shown that the flight strategies of migrating hawks are often influenced by geographical and meteorological factors. Finally, several studies have examined the dependence of avian soaring flight on diurnal fluctuations in thermal intensity (Haugh 1972, 1974; Larkin, 1982; Pennycuick, 1989). These relationships form the backbone upon which bird abundance, distribution and flight forecast models could be developed because the variables that govern changes in these patterns are often predictable.

The bird flight forecast model (BFFM) currently under development is designed to explicitly model those processes that govern avian abundance, distribution and flight patterns. The accuracy of any forecast model is ultimately dependent upon the strength of the relationships upon which the model is developed. Establishing solid relationships requires the proper identification of those processes that govern avian abundance, distribution and flight patterns, and the gathering of data necessary to develop these relationships. We are currently exploring these relationships for several species of birds. These species include American White Pelicans, Turkey Vultures, Black Vultures, and Swainson's Hawks. Preliminary results from our study of American White Pelicans, Turkey Vultures, and Swainson's Hawks follow.

Preliminary Results

a. Data and Methodology

During June and July 1997, we monitored the movements in the Fallon, NV area of 10 American White Pelicans instrumented with satellite telemetry transmitters. Two two-person teams followed these pelicans during their daily flights, obtaining high-resolution altitude data (at approximately 70-second intervals) from the transmitters attached to these birds. Each team also made observations of bird behaviors and weather conditions when possible. These data are currently being analyzed in relation to the habitat, geography and weather observed in the area. This paper describes the

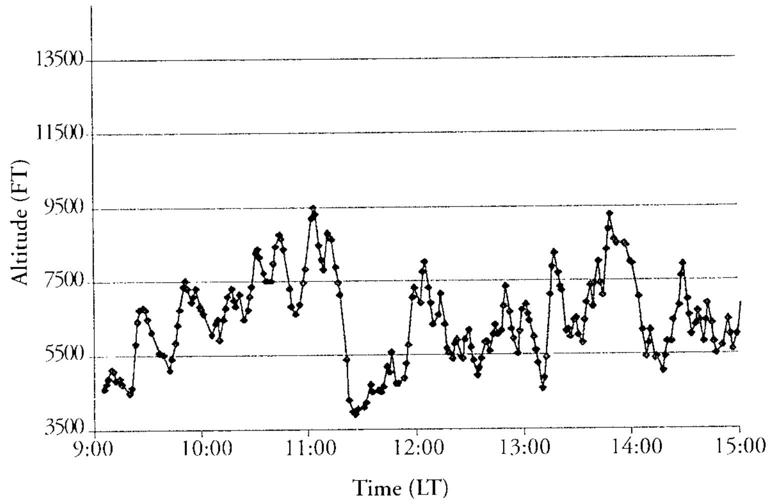


Figure 1: *Flight altitudes for pelican 5720 on 7 July 1997.*

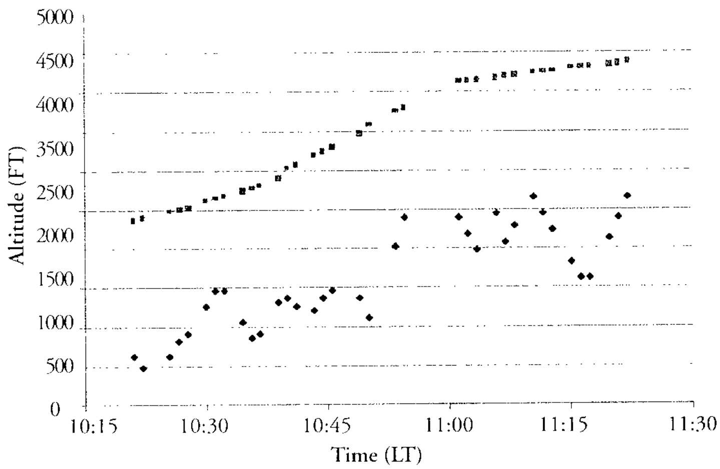
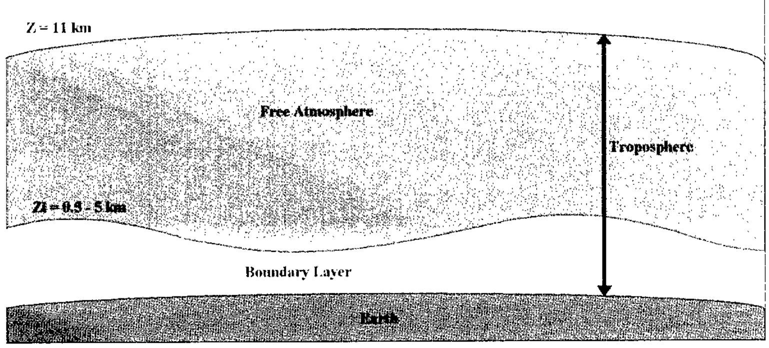


Figure 2: *Flight altitudes for pelican 5722 (dots) and thermal depth (green line) for 16 June 1997.*



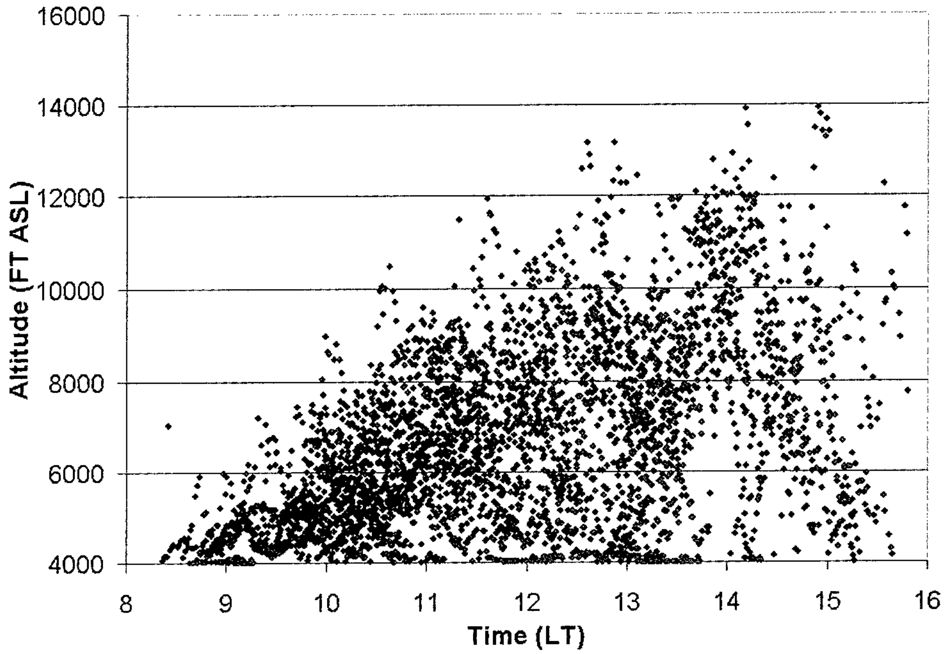
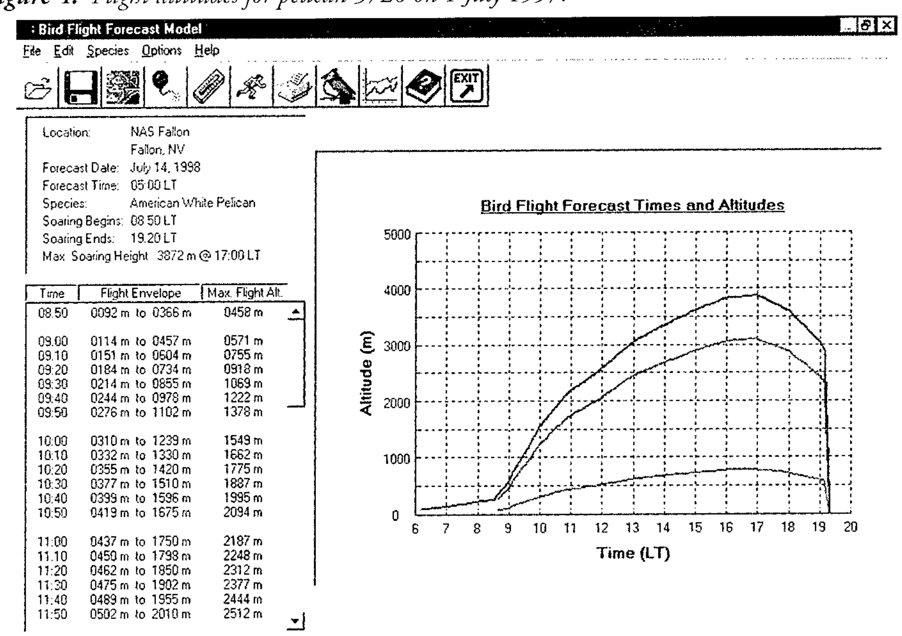


Figure 3 *Illustrates the forecast thermal depth and observed flight altitudes for one instrumented pelican on 16 June 1997. As thermal depth increased throughout the morning the altitude of the pelican flight envelope also increased. Furthermore, the pelican flight envelope remained in the middle of the thermal layer. A comprehensive statistical analysis of all telemetry and meteorological data is currently underway to verify the strength of these relationships.*

Figure 4: *Flight altitudes for pelican 5720 on 1 July 1997.*



relationship between pelican flight altitudes and changes in the weather as discovered during this field study. Preliminary results from this analysis suggest that by predicting changes in environmental factors we can predict changes in the times and altitudes of pelican flight.

b. Results

Figure 1 illustrates the temporal evolution of the flight envelope for one instrumented pelican on 7 July 1997. The morning data were gathered as the pelican completed an approximately 100-km flight from its foraging grounds to its breeding colony. After a brief stop at the breeding colony, the bird returned to its foraging grounds via the same route. This figure shows that relatively low-level flight in the morning evolves into higher-level flight during the afternoon. This increase in flight altitudes is related to an increase in thermal depth and intensity throughout the day. Figure 2 illustrates the temporal evolution of the flight envelope for the same pelican on 1 July 1997. In contrast to figure 1, the flight envelope does not continue to increase throughout this day because the sinking air associated with a high-pressure system limited thermal depth during the late morning and early afternoon. Given that the primary mode of flight for American White Pelicans is soaring flight, these results suggest that forecasts of thermal depth and intensity can be used to forecast the times and altitudes of the pelican flight envelope.

The above graphs depict very preliminary altitude data gathered from a Swainson's Hawk in Canada and a Turkey Vulture in Texas during fieldwork carried out in the summer of 1998.

Discussion

The value of wildlife monitoring programs, radars, and bird avoidance models in reducing the bird strike hazard to aircraft is significant. These tools combined are capable of providing information on historical and real-time changes in bird abundance and distribution patterns. Unfortunately, these tools are either diagnostic or climatological in nature, and therefore provide little detailed information on expected changes in bird abundance and distribution patterns. Anticipating changes in these patterns prior to their occurrence is critical to reducing the bird strike hazard to aircraft. By combining wildlife monitoring programs, radars, and bird avoidance models with bird flight forecast models it is possible to develop an efficient and accurate bird flight forecast and information system. This system would provide information on past, present, and predicted bird abundance and distribution patterns, and could provide this information in a similar manner as weather information is made available to the aircraft community today. A demonstration snapshot of the Bird Flight Forecast Model is shown below.

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Next Generation Satellite-Based Technology for Conservation and Bird Strike Science

William S. Seegar[a], M. Blake Henke[b], Matthew Schor[c], Michael Stone[d]

[a] Ph.D., U.S. Army, Aberdeen Proving Ground, MD,
[b] Center for Conservation Research & Technology (UMBC),
[c] SkyBitz, Inc., Herndon, VA,
[d] SkyBitz, Inc., Herndon

Introduction: To date, Service Argos is the only practical satellite system available to track and monitor small, free-ranging animals on a large (in some cases global) scale. We have worked extensively with the Argos system and have fielded small platform transmitter terminals (PTTs) capable of tracking a bird the size of a male peregrine falcon (see examples of birdborne PTTs below).

These capabilities have enabled us to track the local, regional, and global movements of birds, some on transcontinental migrations of thousands of miles. Argos will continue to be the only satellite system capable of monitoring a device that small (20 - 120 grams) and that low in power output (125 to 375 mW), at least for many years to come.

However, with the advent of new Low Earth Orbit (LEO) satellite systems, such as Globalstar, ICO, and Iridium, new and more capable satellite transmitter technology will soon be possible in transmitter packages weighing about 200 grams or less to start. This technology will evolve into smaller packages in time and will provide two-way communication, as well as tracking and monitoring with an accuracy of +30 meters on a global scale. The development and application of these new LEO systems is the topic of this paper. The possibilities that exist with these new systems for conservation and bird strike research are immense and will be explored.

Background

Conventional biotelemetry systems, developed in the 1950s and 1960s, use directional receiving antennas to locate radio transmitters. Conventional biotelemetry systems, however, are typically restricted to small geographic areas accessed on foot, from automobiles, or by aircraft. A miniature, satellite-received transmitter that is light enough to be carried on the backs of birds was first developed by the founders of the Center for Conservation Research & Technology (CCRT) in the mid—1980s. The transmitters, called platform transmitter terminals (PTTs), are located and tracked by the Argos satellite system, which is capable of tracking mobile organisms anywhere on the face of the Earth with an accuracy of ± 150 m to 3 km (depending on the angle of

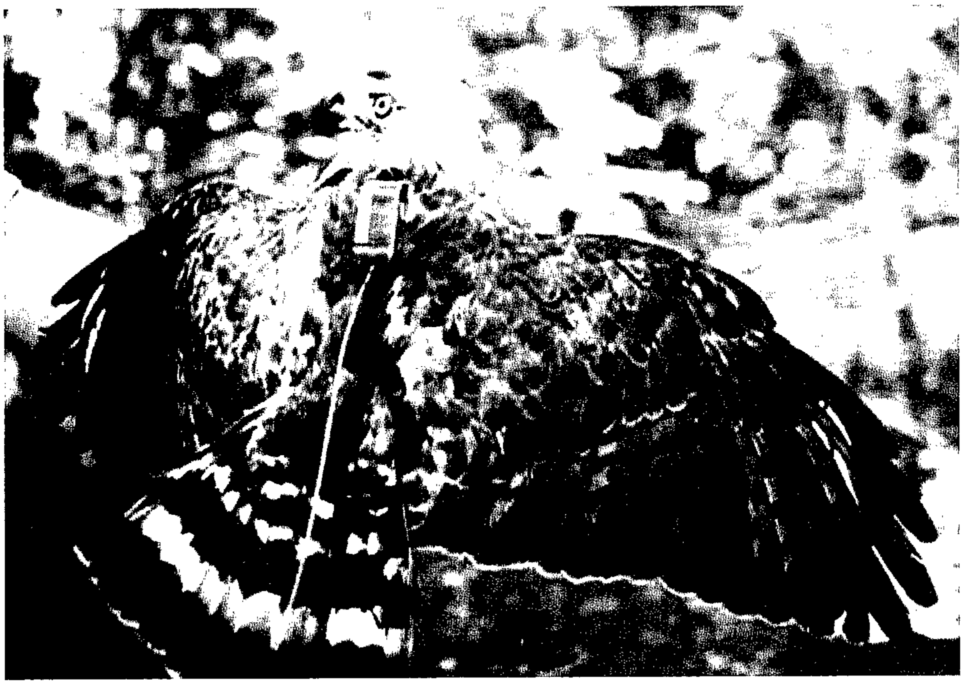
the satellite pass and the quality of the PTT transmission). In 1984, we placed the first experimental satellite received, PTT on a Bald Eagle at Aberdeen Proving Ground, Maryland and tracked it for 270 days between Maryland and Florida. Since then, miniaturization has led to the commercialization and fielding of PTTs that can weigh less then 20gm and can interface with an array of sensors. These space-based technology tools are particularly applicable for studies of free-ranging animals that (1) travel long distances over extended periods, (2) frequent rugged, inaccessible habitat, or (3) occupy secure areas (such as military installations). Today, these advanced biotelemetry capabilities incorporate the latest innovations in microelectronics, geographic information systems (GIS), remote sensing, and computer modeling and offer great promise in helping to define and characterize human effects on species and ecological communities and to identify strategies to ensure their sustainability in the face of expanding human enterprise.

CCRT analyzes satellite-derived tracking and monitoring information with geographic information systems (GIS) to map animal movements in relation to habitat types, geo-political boundaries, vegetation cover, geomorphology, water resources, military land use activities, and many other geographically discrete data sets. In this way, we can provide critical resource management
information to land managers, and in many cases this information is not attainable in any other way.

Swainson's Hawk migration data Peregrine Falcon migration data

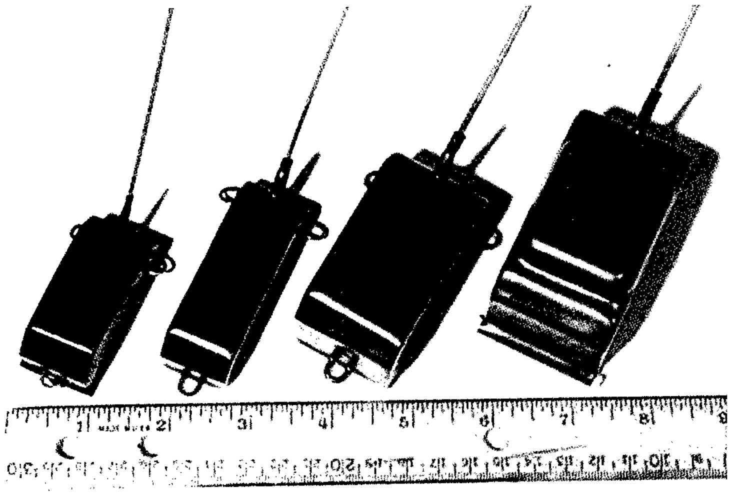
The above maps portray information gleaned from two comprehensive studies CCRT has undertaken, one involving Swainson's Hawks and one regarding Peregrine Falcons. CCRT pioneered the application of space-based technology for the study of Neotropical migratory birds in the Americas. We successfully developed a methodology and study protocol for application of satellite tracking to Tundra Peregrine Falcons (Falco peregrinus tundrius) and Swainson's Hawks (Buteo swainsoni) using the smallest available PTTs. In only a few years, these transmitters have provided more data of Peregrine Falcon migratory patterns than the past 25 years of conventional field studies and leg band returns. Scientists are now learning exactly where these birds travel, where they stop along their trek, and what threats may exist to their survival along the way. And our work with the Swainson's Hawk — i.e., tracking individuals from throughout their breeding range to wintering areas in the pampas of Argentina — revealed the cause (massive mortality from chemical pesticide applications in Argentina) of a potentially catastrophic population decline that could have affected 90% of the North American population. In fact, this study (conducted with many collaborators) may have prevented listing of the Swainson's Hawk on the threatened and endangered species list.

Through support from the DoD's Strategic Environmental Research and Development Program (SERDP), CCRT has fielded a Global Positioning System (GPS) PTT, new

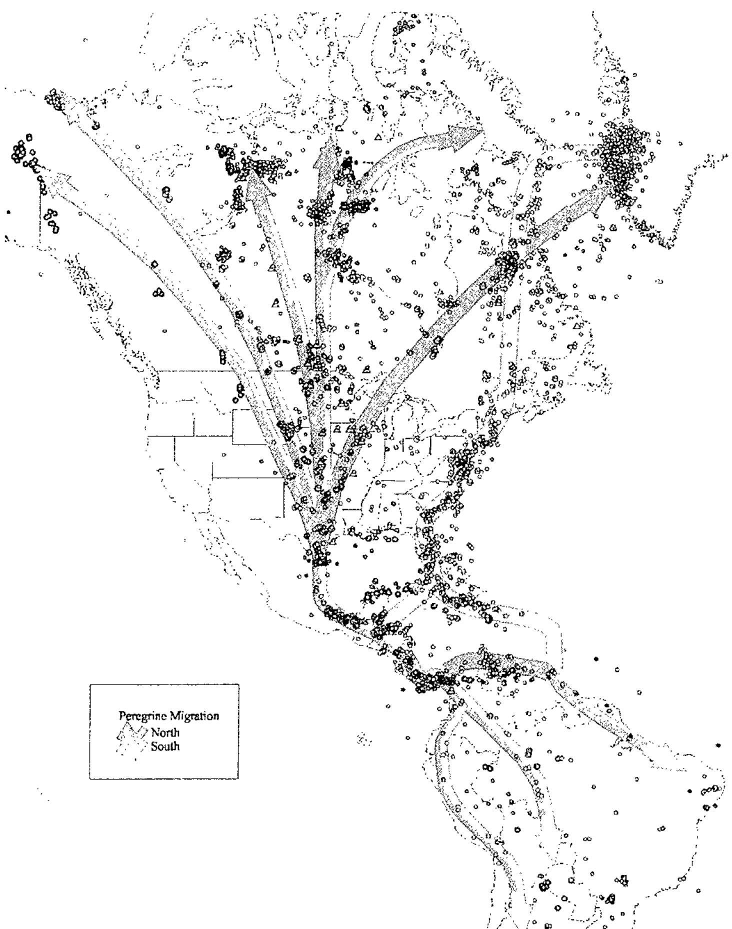


Broad-winged Hawk with PTT

Tundra Peregrine Falcon with PTT in western Greenland (Photo: Blake Hanke)



Commercially available satellite PTTs for birds. From left to right, 22 gram PTT, 32 gram PTT, 80 gram PTT, and 120 gram GPS PTT. Also available (but not pictured0 are solar PTTs in 42 gram and 74 gram packages. Power output ranges from 125 mW to 400mW, depending on the size of the unit (and the battery)



Tundra Peregrine Falcon breeding and wintering ground locations and migration routes determined by CCRT via satellite telemetry.

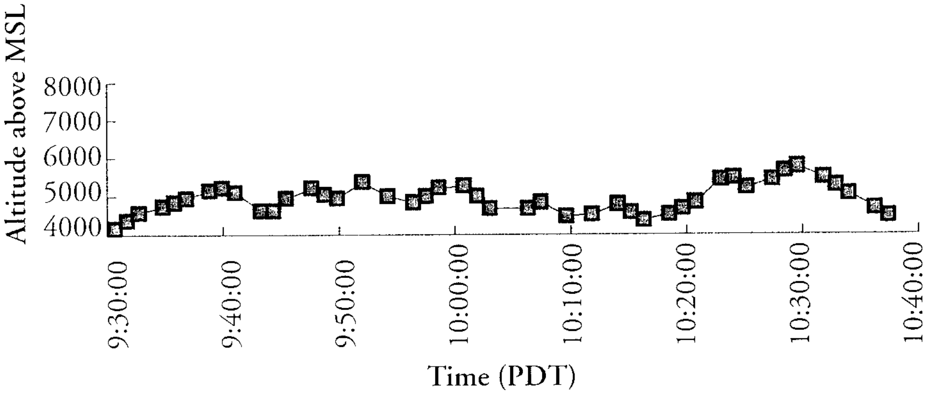
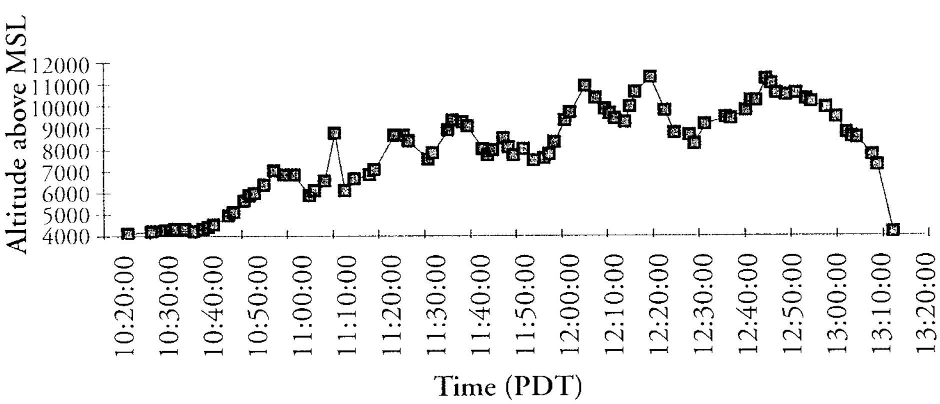
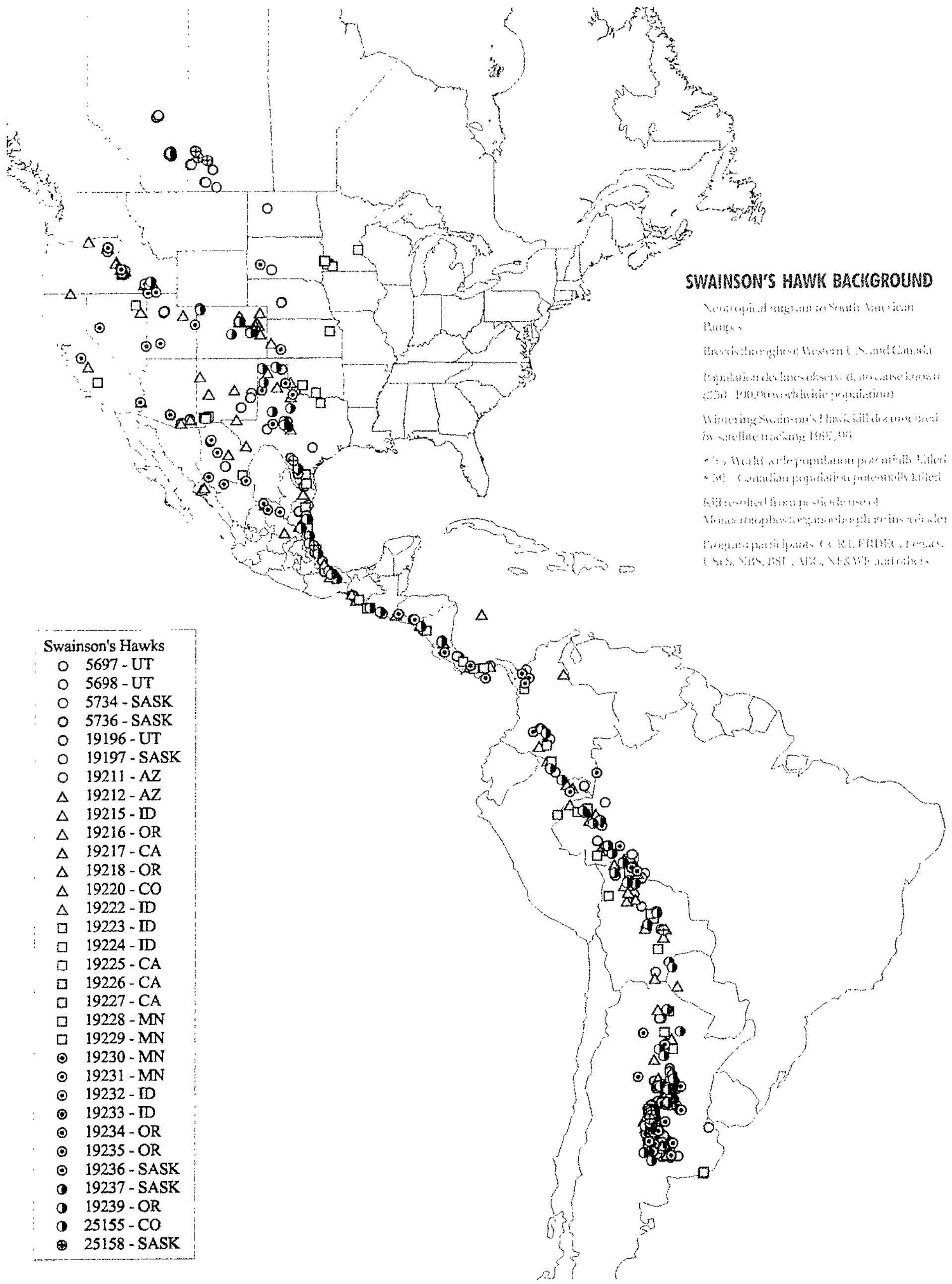


Figure 1 *(above) shows the temporal evolution of altitude for one radio-tracked pelican as it flew across Naval Air Station Fallon, NV from Stillwater National Wildlife Refuge to Carson Lake on June 10, 1997. The altitude envelope of this flight results from the depth of thermal updrafts the pelican used to gain altitude, reaching only a few thousand feet above the runway on this day. In contrast,* ***Figure 2 (below)*** *shows the temporal evolution of altitude for another radio-tracked pelican on a day with weather conditions favoring deeper thermal updrafts. The second pelican's altitude envelope reaches much higher flight levels as a result. These figures illustrate how forecasts of the hourly and daily changes in the thermal updraft depth can be used to predict the time-varying, vertical extent of the soaring bird strike hazard.*





Migration paths of Swainson's Hawks outfitted with satellite PTTs in the western U.S. and Canada.

meteorological sensors, as well as an acoustic sensor that is small enough to be integrated into a PTT to perform a variety of functions. As a result, a new, more capable generation of satellite tracked PTTs is now available for deployment. The new GPS PTTs provide location estimates to within + 100 m, which represents a quantum leap forward in the application of radio telemetry to wildlife science. GPS readings can be collected according to a pre-programmed schedule to dramatically increase the number of positions that are possible (via satellite) and to enhance our ability to derive important facts regarding species range and habitat use.

CCRT is defining the cutting edge of remote tracking and monitoring capabilities. And most importantly, we are using these advanced systems and the resulting data to provide comprehensive analyses and new approaches to pressing wildlife management concerns, nationally and globally, as well as to applied operational and safety issues such as aircraft bird strike avoidance. CCRT is developing a Bird Flight Forecast and Information System to reduce the risk of bird/aircraft collisions. Minimizing this bird strike danger without compromising the flight mission requires forecasts of bird activity with lead times compatible with operational planning. The daily cycle of soaring bird activity varies substantially in response to the changing weather. Therefore, reliance on statistical averages of bird behavior incurs both excessive risks and undue flight restriction. Daily soaring bird forecasts with adequate lead times are therefore essential to meet mission requirements of military aviation units. Our studies of soaring bird flight suggest that such forecasts are possible and can be provided in much the same way that weather forecasts are made available to mission planners. By combining satellite and conventional, radio telemetry tracking technology with meteorological observations and models, CCRT is developing a bird flight forecast and information system to predict potentially hazardous bird strike conditions hours and days in advance.

Next Generation Technology

The recent, rapid evolution of the satellite communication market has opened up new possibilities in geolocation. New devices used in geolocation applications, with 2-way messaging capabilities, could have an immediate impact in applications such as wildlife tracking, bird strike science, oceanographic and atmospheric science, as well as many large commercial markets, such as shipment tracking, cars, boats, ships, railroad cars, trucks, etc.. These new systems could eclipse existing technology very quickly, and could generate new market niches for low priced, highly accurate, 2-way communications and location systems. These new systems will take advantage of new Low Earth Orbit (LEO) systems, such as Globalstar and ICO.

SkyBitz, Inc. has developed a suite of technologies for tracking remote transmitter/receivers via satellite; these are known collectively as the Global Locating System (GLS). Their techniques range from a single LEO satellite that uses a combined Doppler and Ranging measurement, to a multiple satellite time of arrival technique. All of these techniques are aimed at providing a near instantaneous position fix to overcome the

limitation of Global Position System (GPS) receivers, which suffer an inherently long Time-To-First-Fix (TTFF).

Today GPS receivers are commonly placed on objects to be tracked. Position is calculated by the GPS receiver, and then the position is transmitted via satellite (or other communications system) to a central location. This method suffers from the Time-To-First-Fix (TTFF) limit inherent in GPS receivers upon waking up from a cold start. From the cold start state, a GPS receiver must download the GPS satellite almanac, ephemeris, and clock correction information. This process currently takes anywhere from 90 seconds to many minutes, causing a rather high demand on an on-board battery. The TTFF limit effectively eliminates using a GPS receiver in situations where a long TTFF is unacceptable, such as frequent tracking of mobile objects. The Global Locating System approach, can calculate a position fix in three seconds, saving more than an order of magnitude in both time and power consumption on the battery. This represents a breakthrough capability, allowing for tracking of assets for years at a time (at four position reports per day), whereas the GPS- based approach has at most a thirty-day battery life.

While the Argos system currently can track birds with a small transmitter and low power consumption, the Doppler approach suffers from relative low accuracy, and the antenna size at 401 MHz is relatively high. Argos has also been used as a pure communication channel to relay more accurate GPS derived positions, but this compromises the long battery life goal. A solution is to integrate SkyBitz, Inc. GLS technique with the Doppler measurement from Argos. These efforts will commence in calendar year 2000.

Conclusion

The solution to today's unique geolocation application design requirements–based on preliminary efforts–may well be in the use of highly integrated CDMA chips that have already shown great promise. CDMA is a highly efficient way of using the available radio spectrum. Using it enables the designer to solve both the geolocation requirements and the two-way messaging needs in a single waveform while eliminating the interference normally found in other systems. In the geolocation approach, a ground terminal is interrogated via satellite from another ground station. The transmitter terminal, in turn, generates a signal to be uplinked. This return signal contains all the required user data and acknowledges the initial signal. When received back at the ground station, the return data are demodulated, and the position is calculated based on the characteristics and information contained in the signal from the transmitter terminal.

This geolocation approach utilizes a combination of time of arrival and frequency on arrival to determine location. The accuracy of this approach rivals the results of any GPS-based solution.

The Spread Spectrum waveform far exceeds the strength of traditional GPS-based

systems. It can penetrate concrete walls and floors of buildings, thereby making precise locating of objects, such as automobiles in hi-rise urban parking garages, quite easy. This approach offers great promise for animal tracking and monitoring in unfavorable environments and, when combined with an Argos PTT, may also yield small, low power transmitter terminals suitable for many species of birds. Research and development will continue, and the possibilities that exist with new geolocation techniques and new satellite systems will be fully explored in multiple, parallel paths.

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The Avian Hazard Advisory System

T. Adam Kelly[a], Ronald Merritt[a], Maj Thomas J. Donalds[b] and Ronald L. White[a]

[a] 3160 Airport Rd, Suite 22-A, Panama City, FL, 32405
[b] 4th Wing, Seymour Johnson AFB, NC.

Abstract

The Air Combat Command (ACC) Bird Hazard Working Group (BHWG), in conjunction with Geo-Marine Inc., has developed a system to use NEXRAD weather radar data, weather forecasts, and known bird distributions, to identify bird hazards to military aircraft conducting low altitude, high speed training, and provide aircrews with hazard advisories. The paper presented here describes Phase I of AHAS implementation, the demonstration and validation phase, conducted during the fall 1998 migratory season in the Northeast U.S. Forecasts of bird activity for the next 24 hours, observations of current migratory conditions and historic data from the US Bird Avoidance Model (BAM) were provided to aircrews via the Internet. Phase II will expand coverage to the entire East Coast of the U.S. in 1999. The Avian Hazard Advisory System (AHAS) was designed to pinpoint actual bird movement to allow for more effective risk management than is possible from historic data alone.

Background

Geo-Marine Inc and HQ Air Combat Command (ACC) conducted a risk assessment of bird strikes during low altitude training in 1997. Risk was defined as number of strikes multiplied by body mass.
The results (table 1) showed that 94% of the risk came from just ten groups of birds.

1	Turkey Vulture
2	Red-Tailed Hawk
3	Snow and Canada Geese
4	Ducks (Mallard and Pintails)
5	Golden and Bald Eagles
6	Black Vulture
7	Herring Gull
8	Sandhill Crane
9	White Pelican
10	Tundra Swan
11	Double Crested Cormorants

Table 1

An eleventh species was added in 11th position in the table due to rapid population growth and flight behavior that makes a strike on low altitude missions highly likely in the future. These became the priority species for risk management by the Air Combat Command (ACC) Bird Hazard Working Group (BHWG). 7 groups in table one (in italics) can be detected on the NEXRAD (WSR-88D) weather radar. The remainder is not reliably detected at the normal densities found in N. America due to processing techniques employed by the radar. The activity of these species can only be predicted from weather conditions and cannot be monitored in near real time.

The AHAS concept was developed by HQ ACC/SEF and funded by HQ ACC/DOR to manage the risk to ACC aircraft conducting low altitude training. ACC has the greatest exposure to bird strikes of all branches of the United States Air Force (USAF) due to the nature of their mission. Over the past twenty years, the Air Force has reported more than 30 aircrew fatalities, 20 lost aircraft, and hundreds of millions of dollars in damage.

In the fall of 1998 the Avian Hazard Advisory System (AHAS) was tested by HQ ACC and Geo-Marine, Inc. In the test phase AHAS provided USAF with a means to monitor and predict potentially hazardous bird activity along selected regions of the Atlantic Coast of the United States.

The aim of AHAS is to
a) Prevent loss of life
b) Prevent the loss of aircraft and
c) Reduce the cost of bird strike damage.

Project Description.

AHAS consists of the following elements:
- A forecast of bird migratory activity for the next twenty-four hours.
- A forecast of soaring bird activity for the next twenty-four hours.
- Near real time monitoring of bird activity with NEXRAD radar.
- Radar Data archiving for system development.
- A link to the US Bird Avoidance Model (US BAM).

Forecasting

AHAS is a dynamic version of the US BAM. The US BAM is based on historical data on where large concentrations of birds are located and when they are active. The US BAM integrates this data in a Geographic Information System.

AHAS takes current weather data from the National Weather Service and calculates the risk large bird species present, based upon the relationships found between behavior, weather and strike rate with each species. Standard meteorological calculations are used to determine thermal depth and strength that gives Red-tailed Hawks the energy

to soar over their territories and Turkey Vultures the altitude to cover long distances when searching for food. Weather data is also used to determine when birds will initiate migration. A new rule based forecast technique was developed to predict when weather conditions favor migration. This technique was considered more stable and predictable than results from conventional statistical techniques.

Test results show that AHAS can predict bird conditions 24 hours in advance. These 24-hour predictions are often less restrictive than the US BAM because AHAS forecasts recognize that birds don't migrate with strong headwinds or soar without thermals. In some cases, the AHAS forecast may identify higher risks than predicted from the historical US BAM data.

Near real time monitoring

AHAS uses the Next Generation Weather Radar, WSR 88-D (NEXRAD) weather radar system to monitor bird activity in near real time. Birds are, in simple terms, bags of water, so sensitive radars such as NEXRAD cannot differentiate between bags of water wrapped in feathers or the same volume of water distributed as precipitation. Birds do differ from rain in one important aspect. Rain tends to have both vertical and horizontal distribution. A storm can be 20 to 30 thousand feet up and cover many square miles on the ground. Large movements of birds tend to lack any significant vertical distribution. Most birds on the East Coast fly below 4000 ft and elsewhere below 12,000ft.

By some clever data processing it is possible to remove much of the weather from the radar data due to the vertical distribution of the precipitation and leave the bird returns. This technique was developed for the AHAS project and provides a means to turn off and on the risk levels presented in the US BAM in near real time. This eliminates the need to identify the type of bird target on the radar. The logic used is that if bird activity is detected by NEXRAD in an area where hazardous bird activity is expected by the BAM then the area is designated as hazardous by AHAS.

This system provides for regular updates (approximately 20-35 minutes old) of current bird conditions. These are posted at hourly intervals via the internet and provides information that can give a Supervisor of Flying (SOF) or a pilot the real picture on current flying conditions.

Link to the US Bird Avoidance Model.

The AHAS system has ported NEXRAD NIDS data to a GIS platform. This provides a means to relate bird activity detected by radar to known hazardous concentrations described in the BAM. With weather targets largely removed from the radar images this allows for an automatic interpretation of the worst case risk situation for the detected targets. This removes the need for human radar image interpretation, a time consuming process, which would add excessively to the timeliness of the risk analysis. The GIS is

used to extract risk information that is made available to aircrews via the Internet in near real time.

When radar or weather data is not available to AHAS then the system automatically defaults to the risk described in the US BAM. This ensures that the best available data is always available to pilots, aircrew and commanders via the Internet.

Radar Data Archiving for System Development

The AHAS system has capability to archive all GIS images of radar data, weather observations and forecast model data. This provides a means to test weather suppression techniques and new data products on actual data for rapid system development. New methods and data products can be tested on weather conditions that may take 12 months or more to experience in operational testing. It also permits forecasting techniques to be further refined based on a larger set of observations. This archive is also considered an important feedback loop to the US BAM as one of the highest fidelity sources of data on the historical spatial distribution of birds.

Results

Observations and predictions made from the Panama City, FL, base were validated in the field by biologists equipped with a mobile radar system and thermal imaging camera, a system capable of very accurately monitoring and describing bird activity day and night.

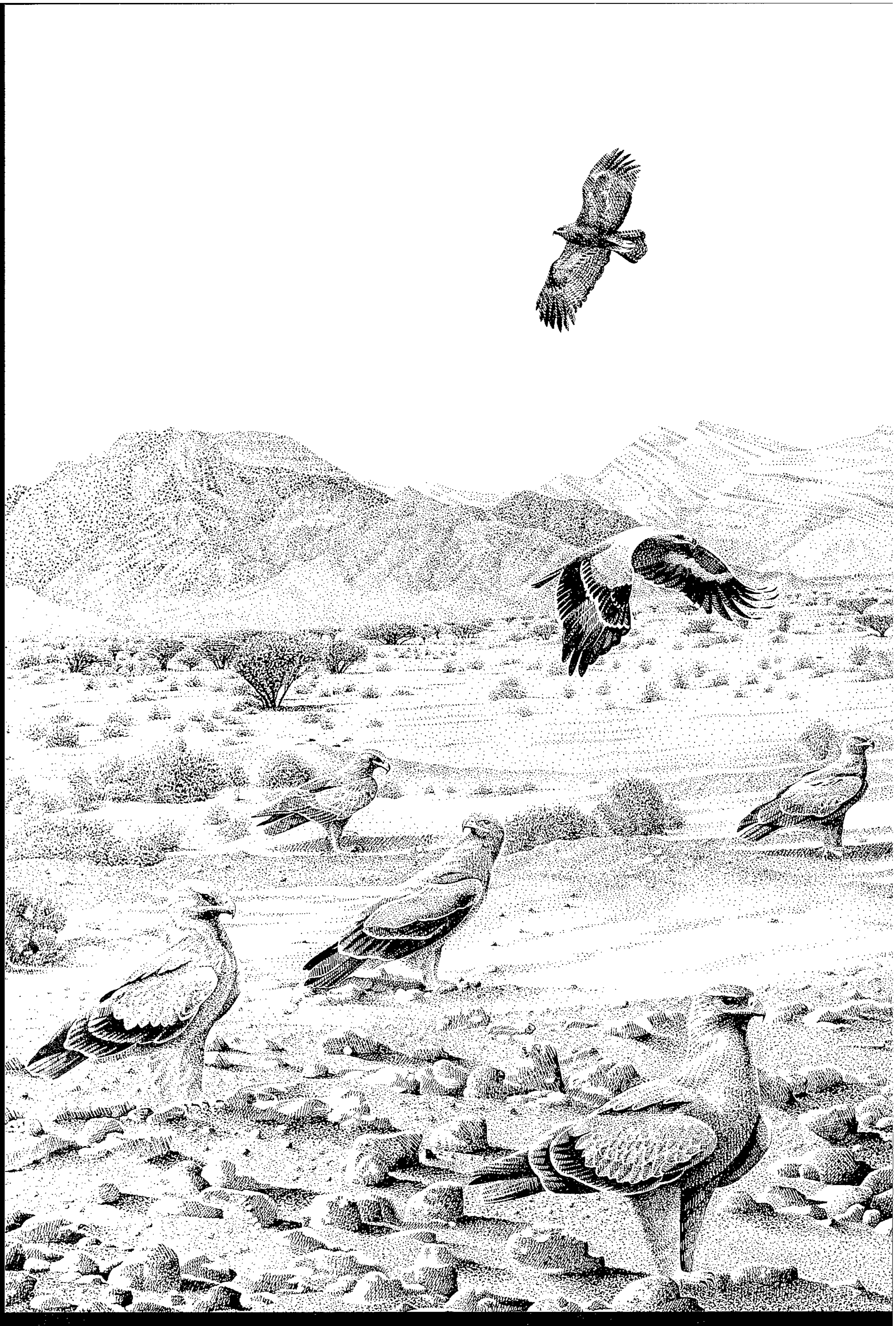
During the fall of 1998, many migrant waterfowl stayed in Canada, due to exceptionally mild weather conditions, until well after they would be expected in the northern states. When the weather changed in November it occurred right before the Veteran's Day holiday. A warning was posted on the AHAS site 36 hours ahead of the worst of the migration hitting the East Coast. Twenty-four hours after the warning was posted, most of the migration corridors in the lower 48 states were saturated with migrating waterfowl. The northern states, where the birds would normally stop over, were covered in six inches of fresh snow so the birds pressed on. Based on these observations, HQ ACC/SEF issued a bird warning via e-mail to all flying units as they returned from the holiday . The forecast system showed probabilities of one, the highest possible, for this significant event.

The initial test was considered an overwhelming success. Bird hazard forecast models and radar data processing protocols evolved quickly to provide rapid data analysis and risk assessment. The PC based platforms were down less than 12 hours (0.8% of the time) during the 1,464 hour test period. Daily bird hazard forecasts were posted each morning at 1000 hours on a dedicated website. The forecast covered the entire airspace designated for the test and provided risk assessment for each segment of the designated low-level routes. These forecasts were based upon bird distributions from the BAM and corrected risk based upon weather forecasts and previous days bird movements

from radar data. Hourly advisories were provided based upon filtered radar data. During this test period, the US BAM reflected the expected large concentrations of waterfowl. While most biologists agree that the real risk exists only during portions of this time, few were willing to estimate when those periods were without the benefit of weather data and actual field observations. AHAS, using hourly weather information, weather radar data, and field observations resulted in less restrictive advisories 49.2% of the test period. AHAS yielded the same level of restrictions 40.2% of the time and was more restrictive 10.6% of the test period.

Future Development.

The system is currently being expanded to cover 1/3rd of the lower forty-eight states in phase two and within two years should cover the entire lower 48 states. Real time updates and forecasts will again be posted on the internet and coverage will expand to cover all VR and IR routes, MOA's, Ranges, LATIN Areas and military airports in the eastern 1/3rd of the US by the end of the year. Refinements to the weather suppression technology used on the NEXRAD radar images are planned. Additional bird data products are also planned based on advanced processing techniques of NEXRAD radar images.



Three decades of tracking radar studies on bird migration in Europe and the Middle East

Bruno Bruderer

Swiss Ornithological Institute, CH-6204 Sempach, Switzerland

Abstract

Since the late 60s the tracking radar "Superfledermaus" has been used by the Swiss Ornithological Institute to determine the quantity of migratory passage and to track selected bird-targets in order to record their flight paths and echo-signatures. Tracking of wind-measuring balloons allowed to calculate the airspeed and heading of the birds and to explain considerable parts of migratory behaviour by wind. While the radar remained essentially the same over the years, the recording equipment was continuously improved, to reach a completely computerized set-up in the 90s. In the 90s infrared and moonwatch observations were increasingly used to complement the radar studies.

The results are presented in the form of a review of the research done by the Swiss Bird Radar Team until the end of the 90s. The focus is first on migratory behaviour in general, seen under the differing environmental conditions in the lowlands of central Europe, in the Alps, in the western Mediterranean and in southern Israel. Finally, some general aspects of bird migration in relation with the three ecological barriers, the Alps in central Europe, the Mediterranean Sea in Spain, and the Saharo-Arabian desert belt in southern Israel, are considered.

Introduction

The overall subject of bird migration research at the Swiss Ornithological Institute was to understand the influence of environmental conditions on migration. Radar studies were concentrated on the temporal and spatial course of the movements and on flight behaviour en route, mainly with respect to topography and weather in nocturnal migration. The first geographic area for research was central Europe with the Alps supposed to be a considerable vertical barrier modifying the course of migration. Later, the extended ecological barriers of the Mediterranean Sea and the adjacent Sahara Desert were included as research targets. This paper aims at a comprehensive review of the Swiss Bird Radar Team's work over the last 31 years, providing a complete reference list. The structure of the methodological part is designed to show the basic methods and their development

over time. The results provide a brief summary of the work done with respect to migratory behaviour under various conditions and in relation to the three barriers.

Methods

A general update about the technical basis of radar ornithology was provided by Bruderer (1997a). The present paper concentrates on the use of the tracking radar "Superfledermaus".

The "Superfledermaus"

The tracking radar "Superfledermaus", produced by the firm Oerlikon Contraves AG, became the standard radar for tactical air defence in the Swiss Army from 1963 onwards. It was equipped with MTI (Moving Target Indicator for electronic clutter reduction) from 1969 onwards and was gradually replaced by the "Skyguard" radar after 1975. In the first years the Swiss Ornithological Institute got the radars on loan from the producing firm, later from the Swiss Army. When the last "Superbats" were removed from the army in the early 90s they were transferred to the institute. In ornithological research the radar was used without MTI whenever possible, in order to avoid reduction of targets with low radial speed. To screen the radar off against ground clutter, a natural or artificial hollow with ideally 30 to 40 m radius and an altitude of the surrounding dam of about 2.5 m was required.
The radar is characterized by 3.3 cm wavelength, 150 kW peak pulse power, 0.3 ?s pulse length, and a pencil-beam with a nominal width of 2.2 . Tracking is achieved by a moving distance gate and the beam conically scanning at a rate of about 30 Hz around the optical axis of the parabolic antenna with an offset of 1 . M inimum distance for detection is about 100 m, maximum range for tracking a single Chaffinch Fringilla coelebs in tail-on view (i.e. with minimal radar cross-section) is 4 to 4.5 km. The nominal tracking accuracy is 0.06 in azimuth and elev-ation, and ± 10 m in distance.
The radar remained the same over the years, except that a log-linear amplifier with improved signal to noise ratio and stability was integrated in the 90-ties. The radar allows the acquisition of three types of data: (1) Data on the quantity and spatial distribution of migrating birds over time, (2) data on the flight paths of singly tracked birds and wind-measuring balloons; the latter providing information on winds at the altitude of bird flight and allowing to calculate the headings and airspeeds of the tracked birds from vector addition of bird and balloon track, (3) echo-signatures of tracked targets providing information of the amplitude variation of the echos, part of them caused by the birds' wingbeat pattern.

Recording the Numbers and Spatial Distribution of Birds

The first method applied to record the quantity and spatial distribution of birds was a fixed vertical beam method supplemented by measurements at low angles (perpendicular to the principal direction of migration); registration was first on a dictaphone according to visual observation on the range indicater of the radar; then the Z-modulated range

indicator was recorded by a continuously moving 36 mm film, showing the exact sequence, intensity and passage time of the bird echoes (Bruderer 1971, Bruderer & Steidinger 1972). In order to increase the surveilled space we first used a vertical scanning method, the pencil-beam moving up and down like a height finder radar in a plane perpendicular to the principal direction of migration (Bruderer 1980). Due to considerable disadvantages (variation of the migratory direction around the principal direction and loss of sensitivity due to fast scanning) this method was only used over short time. Conical scanning at various elevations is being considered the most efficient surveillance mode (Bruderer 1992); a full description of the analysis of recorded data is given by Bruderer et al. (1995a). Bruderer & Liechti (1994, 1998d) provided a comparison of various methods to quantify bird migration. Liechti et al. (1995b), comparing the intensity and distribution of bird migration recorded in the pencil-beam of the radar, in the 1.4 beam of a long-range infrared camera, and in the 0.5 degr ee cone of moon-watch observations, showed (1) that the operational beam-width of the radar (at the short working distances used for birds) was about twice the nominal beam-width, (2) that the range of the infrared system (used in dry air towards the cenit) was about 3 km for small birds, while (3) moon-watching usually covered only altitudes below 1000 m a.g.l. with satisfying accuracy.
One of the major problems arising in ornithological studies using X-band radar is that insects are detected by such short-wave radar. Elimination of insect echos was strived for since the beginning (Bruderer 1971) by sensitivity time control (STC). Considerable improvement was accomplished by the introduction of log-linear amplifiers in the 90-ties. However, for large individuals or high density flocks of insects, the problem can not be solved electronically, but only by including information about tracked targets and their echo-signatures (see below).
The volume of migration can be quantified by giving the number of birds per km3 or by the migration traffic rate (MTR), giving the number of birds passing a line of 1 km perpendicular to the principal direction of migration in one hour. In the case of the vertical beam, infrared and vertical scanning methods, the passage of birds is measured, thus leading to MTR as the primary information, while the conical scanning method provides the density of migration per height band; these densities are often averaged over a height from ground level to 4000 m above ground. One information can be transformed into the other by considering the average groundspeed in the area (usually between 45 and 50 km/h).

Recording Flight Paths

In the early days, positions of tracked birds were recorded by taking photographs of the radar's instruments every 20 seconds (Bruderer 1971, Bruderer & Steindinger 1972, Steidinger 1972); transition to electronic recording and digital analysis of 20 sec intervals was achieved in the mid-seventies (Bloch et al. 1981); in 1980 digital recording on PC was introduced, with data points being registered every second, and 10 to 20 points being approximated by a regression line to provide average flight data over 10 to 20

seconds (Bruderer et al. 1995). Visual identification of tracked birds was possible by a telescope (12.4x) mounted parallel to the axis of the parabolic antenna.

In any case the system provided data on the birds' altitude, groundspeed, vertical speed, and flight direction. Winds at ground level were mea-sured by hand-held or mounted anemometers, upper winds by tracking pilot balloons. The birds' heading and airspeed were calculated by subtracting the wind vector at the corresponding flight level from the vector of the birds' track. In the early observation periods the time difference between wind measurement and a single bird track could be up to 6 hrs, while later the frequency of wind measurements was increased, so that the difference was stepwise reduced to less than 3 and finally less than 2 hrs (wind-measurements every four hours).

Recording Echo-signatures

Bruderer (1969) provided examples of echo-signatures of various tracked targets together with theoretical explanations of the variation in signal amplitude, showing the difference between the echoes of single birds, two birds, several birds, flocks of different size as well as examples of the wingbeat pattern of typical bird species and insects. Bruderer & Joss (1969) made measurements of the radar cross-section ? of tracked birds and demonstrated its variation at differen viewing angles. A first classification of flight types based on wingbeat frequency and on the duration of beating and pausing phases was proposed by Bruderer (1971). Flapping frequencies between 10 and 17 Hz are those occurring most often in central Europe, fading out towards 25 Hz and occuring only in small proportions below 10 Hz. Recent analyses (unpublished data) show lowest wingbeat frequencies around 3 Hz. In later studies, a more coarse classification of wingbeat pattern was applied according to Bloch et al. (1981), separating in a first step birds with continuous flapping (with a high proportion of waders and waterfowl) from those with intermittent flapping (mainly passerines). Within these main groups different size categories were separated according to the wingbeat fre-quency which is negatively correlated with wing-length and size of the birds. Summarising background information on wingbeat pattern is given by Bruderer (1997a).

Observation Periods and Sites

The tracking radar "Superfledermaus" has been used by the Swiss Ornithological Institute to ob-serve bird migration since 1968. Emphasis was on nocturnal migration, but increasingly observations on diurnal migration were included, paralleled by an increasing interest in identified birds.

In 21 out of 31 years of the period 1968 to 1999 observations were made, mainly during the autumn migration (August to October), fewer during spring migration (March to May), some to record winter movements (November to February), and a few in July to observe roosting flights of Swifts Apus apus. 13 observation sites in different parts of the Swiss Lowlands, 4 in the Alps, 4 in southern Germany, 2 in southern Israel (Arava Valley and Negev Highlands), and 2 in the western Mediterranean (Mallorca and Malaga)

Year	Project (place, year)	Place no	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	Neerach 68	SL1												
2	Bachenbülach 69	SL2												
3	Bachenbülach 70	SL2												
3	Römerswil 70	SL3												
4	Merenschwand 71	SL4												
5	Hahnenmoos 74	SA1												
6	Hahnenmoos 75	SA1												
7	Payerne 78	SL5												
8	Etzel 80	SL6												
8	Lauerz 80	SL7												
9	Merenschwand 82	SL4												
10	Blumenstein 83	SL8												
11	Payerne 86	SL5												
12	Augsburg 87	G1												
12	Regensburg 87	G2												
12	Stuttgart 87	G3												
12	Flaach 87	SL9												
12	Nürnberg 87	G4												
12	Payerne 87	SL5												
13	Eich 88	SL10												
14	Col de la Croix 88	SA2												
14	Les Moulins 88	SA3												
14	Monthey 88	SA4												
14	Kappelen 88	SL11												
15	Eich 89	SL10												
15	Solothurn 89	SL12												
16	Homburg 89/90	SL13												
16	Eich 89/90	SL10												
17	Sede Boqer 91	I1												
17	Hazewa/Arava 91	I2												
18	Hazewa/Arava 92	I2												
18	Sede Boqer 92	I1												
19	Mallorca/Baleares	S1												
19	Malaga 96	S2												
20	Malaga 97	S2												
20	Mallorca/Balearen	S1												
21	Römerswil 99	SL3												

SL = Swiss Lowlands; SA = Swiss Alps; G = Germany; I = Israel; S = Spain

Fig.3) *The observation periods: The first column indicates the number of the years with radar observations. The second column provides the place and year, the third column the region and the number of the place (note that the same place can occur in different years). The shaded areas indicate the duration of the observation periods (to the nearest 5-days period).*

were used to study different aspects of bird migration and flight behaviour, usually over periods of 1 to 3 months.

Results

Summaries and Reviews

Popular summaries on bird migration, including notable parts of radar results were published by Bruderer (1978) and by Bruderer & Jenni (1988). Bruderer (1977) gave a state of the art report on the contribution of radar ornithology to research in orientation, physiology and ecology of migration. Bruderer (1980) summarized ÑRadar data on the orientation of migratory birds in Europe" and (1981) the state and aims of radar research on bird migration at that time. Bruderer & Winkler (1976) and Bruderer & Jenni (1988, 1990) provided first summeries of bird migration across the Alps, Bruderer (1996b) an extended review of this subject. A summary on nocturnal bird migration in Israel (Bruderer 1996a) was included in Hadoram Shirihai's book on the birds of Israel. The technical basis and major achievements of radar ornithology were reviewed by Bruderer (1997a, b). General overviews on migratory directions of birds under the influence of wind and topography at various temporal and spatial scales were presented at a conference of the Royal Institute

of Navigation (Bruderer 1997c) and in a symposium on animal migration organized by UNEP/CMS (Convention on Migratory Species, Bruderer 1998). The most recent review, integrating new results on bird migration in the western Mediterranean, was presented at the 22nd International Ornithological Congress in Durban (Bruderer & Liechti 1999). Bruderer (1978b) and Buurma & Bruderer (1990) summarized suggestions for the application of radar for bird strike reduction.

Influence of Electromagnetic Fields on Migrating Birds

Large sets of routine recordings of nocturnal bird migrants provided no indication of differing flight behaviour between birds flying at low levels towards the radar, away from it or passing it sidewise. Switching radar transmission on and off, while continuing to track selected bird targets by a passive infrared camera, showed no difference in the birds' behaviour with and without incident radar waves. Tracking single nocturnal migrants while switching on and off a strong searchlight mounted parallel to the radar antenna, however, induced pronounced reactions of the birds. By these experiments we could show that under the influence of the X-band radar "Superfledermaus" no relevant changes in flight behaviour occured, while a strong light beam provoked important changes (Bruderer et al. 1999).

On the other hand, there is evidence that homing pigeons could feel the short wave radiation of a radio transmitter. This radiation did not interfere with the initial orientation of the pigeons (Boldt & Bruderer 1994, Bruderer & Boldt 1994, Steiner & Bruderer 1999). Reduced homing speeds of birds grown up without experiencing radiation, and low flight levels in all groups flying under radiation, as well as a general reluctance to fly of pigeons living in a loft next to the transmitter, suggest that the radiation had an negative effect on the birds. Unimpaired homing speeds in juveniles having grown up under varying field strengths near the transmitter, suggest that homing pigeons can become accustomed to short wave radiation to a certain extent (Steiner & Bruderer 1999).

Timing of Migration

Variation Within and Between Seasons

In central Europe the main passage of trans-Saharan migrants starts in early August, peaking mid-September. Increasingly from mid-September onwards pre-Saharan migrants join nocturnal migration, maintaining a high level of migration until mid-October (Baumgartner 1997), then fading out towards the end of October. Some movements of pre-Saharan migrants often go on well into November. Actually there is some migration all throughout the winter with mainly waterfowl movements (Kestenholz 1995), but also some passerines moving by day and night (unpubl. data). The directions of these winter movements depend strongly on weather conditions, but generally directions are scattered in bad weather and towards SW in fine weather until late January; afterwards NE directions prevail (Kestenholz 1995).

In Switzerland, the intensity of spring migration is characterized by much lower densities

than autumn migration. This may partly be due to high mortality of first year passerine migrants; but the main reason is probably that the migrants are concentrated along the Alps in autumn, while in spring a considerable proportion of migrants may be prevented from entering the Swiss Lowlands by the narrow entrance between the Alps and the Jura mountains, the latter deviating the stream of migrants around Switzerland.
In the western Mediterranean nocturnal autumn migration starts very slowly in August and reaches a first peak around mid September. It declines in early October, to reach highest numbers with the passage of pre-Saharan migrants in late October. Spring migration might have a corresponding peak in early March (not recorded by radar) and a minimum in late March, the passage of trans-Saharan migrants peaking mid-April and fading out end of May (Bruderer & Liechti 1999).
Nocturnal autumn migration in southern Israel (i.e. in the semi-deserts of the Negev)

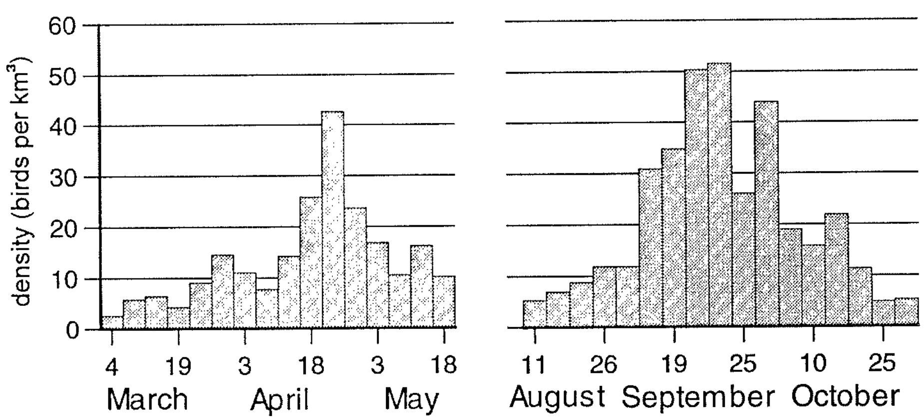


Fig. 4) *The course of nocturnal spring and autumn migration in the Arava Valley. Mean bird densities per night are averaged over five-day-periods to provide a general idea of the seasonal course of bird migration. Note that spring migration is only about 60% of autumn migration. This might be due to mortality during migration and in the winter quarters or due to some birds taking different routes in spring and autumn (loop migration avoiding the Arava Valley in spring).*

starts slowly in August and peaks around mid-September. Different from the western Mediterranean there is only weak passage of pre-Saharan migrants, leading to a pronounced decline of migration towards the end of October, some migration going on into November on the Negev Highlands and further north. Nocturnal spring migration peaks in the last third of April when it is 10 times higher than in the first third of March. In Israel, spring migration comprises about 65% of the volume of autumn migration (Bruderer 1994a, 1996a, Bruderer & Liechti 1995).

Short-term Variation Due to Weather

Highest volumes of passerine spring migration in Switzerland are observed in warm sectors far off the fronts (i.e. when anticylconic conditions are combined with southwesterly winds). Closer to the warm fronts the intensity might also be high, while the flight altitudes

are reduced. Medium densities occur in the central parts of anticyclons, in flat pressure areas and in situations with easterly winds on the S-side of a high. Low density migration is observed to the east of high pressure areas, in areas of precipitation and on the rear side of cyclons (Bruderer 1971). Autumn migration in central Europe is also governed by fine weather and the following winds associated with the passage of cyclons. Optimal conditions prevail when fair weather installs on the rear side of cyclons and on the E-side of high pressure areas. The main inhibiting factors are given by precipitation and strong opposing winds. During periods of bad weather, the number of resting birds and their urge to migrate seem to increase, leading to pronounced waves of migration when weather improves after a sequence of rainy nights (Baumgartner 1997). Even pronounced long-distance migrants like Swifts Apus apus, which are often considered to migrate independently of weather according to their innate schedule, react to the passage of weather systems in a way similar to the main mass of bird migration in Switzerland (Bruderer & Weitnauer 1972).

Thus, for spring and autumn, in temperate regions maximum numbers of passerines are migrating with fair weather and following wind, such conditions occurring in the northern hemisphere when a low-pressure area is to the left and/or a high-pressure area to the right of the main direction of migra-t-ion (Bruderer 1978c). In the absence of precipitation single weather factors other than wind, such as temperature, pressure, cloud cover and visibility which are correlated with these basic weather conditions seem to have only minor effects on the number of birds taking off for migration at night (Baumgartner 1997, Bruderer 1997b).

In the Mediterranean region night-to-night variation in migratory intensity differs between the trade-wind zone and the adjacent parts of the temperate zone: In southern Israel there is no clear correlation between the volume of migration and the relatively weak changes in local weather conditions. Nocturnal migrants seem to travel under nearly any condition because they can always find good winds at a certain height in the trade-wind system (Bruderer 1994, Bruderer et al. 1995, Liechti & Bruderer 1998). In southern Spain, the availability of tailwinds is intermediate between Israel and central Europe, suggesting intermediate reactions of migratory activity to changing weather conditions (Liechti & Bruderer 1998).

Liechti & Bruderer (1998) demonstrated the relevance of wind for the optimisation of passerine migration. Birds migrating through central Europe and the Mediterranean area have to cope with windspeeds reaching often 50 to 100% of their own airspeed. Opposing winds prevail during autumn migration in central Europe, while at the western and eastern edges of the Mediterranean Sea opposing and following winds occur in similar frequencies. In the trade-wind zone of southern Israel the birds can nearly always find good winds by selecting appropriate altitudes, while further north, they have to choose nights with favourable winds. This selectivity for winds is more profitable than adjusting departure to local fat accumulation rates as suggested by various theoretical models (Liechti & Bruderer 1998, Liechti et al. in press).

The Diurnal Course

In inland areas of temperate regions nocturnal migration starts with a few birds, mostly waders or wa-terbirds, during the hour before sunset. The main take-off period starts between half an hour and one hour after sunset, i.e. around dusk. In fair weather, peak densities and highest altitudes are reached 1 to 2 hours after dusk. Migration shows often a slight decrease already around midnight and progressively declines during the second half of the night, usually ceasing before sunrise, unless resting possibilities are limited or lacking. Day migration often starts already before nocturnal migration has completely ceased. Peak densities of diurnal passerine migration are reached around or soon af-ter sunrise. Migration declines in the second half of the morning. Occasionally a slight increase is observed again before sunset, but normally migration fades out during the afternoon. Some species, like Woodpigeons Columba palumbus, start later in the morning than passerines, and soaring birds have their peak migration when thermal activity is highest (Bruderer 1997b).

Studies on the south coast of Spain near Malaga and on Mallorca, the biggest island of the Balearic Islands, allowed detailed analyses of the diurnal schedule of departure and passage due to pronounced gaps in migration according to the distribution of sea and land (Liechti & Steuri 1995, Liechti et al. 1997, Bruderer & Liechti 1999). The take-off phase of nocturnal migrants on the southern tip of Mallorca (only 16 km2 of recruiting area!) in spring, begins on average 13:25 min before sunset (standard error of means SE = 4 min, N = 49 nights), reaches the maximum 64 minutes later (i.e. 51:13 min, SE = 2 min after sunset and roughly 20 minutes after civil twiligt) and comes to an end 200?62 min after sunset. The birds from Africa, after a sea crossing of 300 km and various distances travelled in North Africa arrive much later, with large variation from night to night due to different wind situations en route, on average 8 hrs ?1hr after sunset. Passage at the radar site (8 km NW and 2 km NE from the southern coasts) ceases around sunrise, suggesting that the birds arriving towards morning land on the small surfaces south of the radar (S. Speich unpubl. thesis 1999, Bruderer & Liechti 1999). In autumn the schedule of departures is nearly the same as in spring, but the peak arrival from Europe is about 7 hours after sunset. The autumn take-off at Malaga begins about 15 min after sunset and peaks 2 hrs after sunset, the intensity of passage continuously decreasing until sunrise. In spring, arrivals from North Africa at the Spanish coast (after 170 km sea crossing and various distances travelled in North Africa) begin 3 hours after sunset, peak about 5 hours after sunset, declining steeply in May and slowly in April, fading out around sunrise (Bruderer & Liechti 1999).

Nocturnal migration above the arid areas of southern Israel starts with a few birds around sunset (mainly waders if there are suitable resting areas nearby). About one hour after sunset, i.e. around dusk, there is a sudden rush of passerine migrants taking off. Peak densities are reached soon afterwards in the Negev Highlands, where reasonable resting areas are available all over; in the Arava Valley, migration density increases more slowly, but peak densities are also reached 2-3 hours before midnight. Towards midnight there

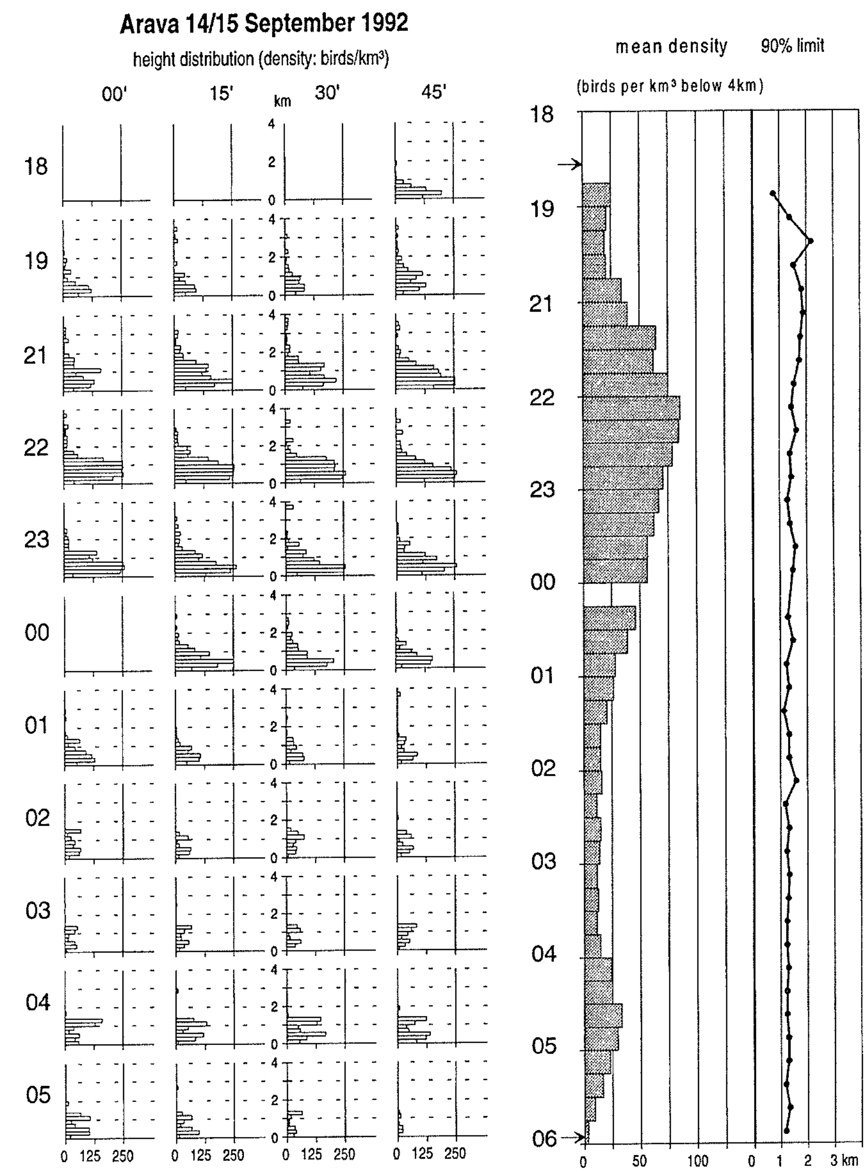


Fig. 5) The course of migration in the Arava Valley during the night of 14/15 September 1992. Automatic measurements every quarter of an hour with an experimental radar which was not used for bird tracking but was continuously available for conical scanning. The diagrams on the left show the vertical distribution of migration in four bar-diagrams per hour (empty diagrams are lacking measurements). The concentration of migrants below 1500 m a.g.l. (i.e. below the windshear of the trade wind system) is typical for autumn migration. The two diagrams to the right show averages per quarter of an hour. The 90%-limit reaches highest levels briefly after the start of migration at civil twilight (indicated by an arrow at 18:40 local winter time = UTC + 2 hrs); this indicates birds searching for optimal wind conditions at various altitudes. From 21 hrs onwards the upper limit of migration gradually decreases. The temporal course of migratory intensity (mean density of birds below 4 km per quarter of an hour) is typical for the Arava in so far that maximum density is reached around 22 hrs; this is late compared to other areas with better resting possibilities nearby. The take-off densities were below

average on this night. An interesting phenomenon, which is not detected by the usual measurements at two hour intervals, is the increase of migratory densities about 9 hours after civil twilight or 8 hours after normal maximum take-off. As the normal groundspeed of migrants in the Arava Valley is about 50 km/h, these birds must have started their migration at the southern coasts of Turkey, crossing the eastern-most part of the Mediterranean Sea, and arriving in a pronounced wave towards morning in the Arava. As this wave is due to land before civil twilight (arrow at 05:55 local winter time) occurrence or non-occurrence of such a wave will considerably influence the quantity of birds resting in the area, and thus the intensity of take-off the next evening.

is already some decrease in migratory activity; the decline progresses during the second half of the night, migration almost ceasing before sunrise (Bruderer & Liechti 1995, Bruderer 1996a). Careful examination of the transitional phase around sunrise reveales that in these arid areas there are, in addition to some diurnal migrants like swallows, a few birds which do not land after nocturnal migration: these are not small passerines like the majority of the nocturnal migrants but usually large birds with flapping flight, such as herons, ibises, spoonbills, flamingos, cormorants, ducks, gulls, terns and some waders. Such continued flights usually coincide with strong following winds, the birds reaching often altitudes of 2,000-7,000 m above sea level (Bruderer 1994, 1996a, Liechti & Schaller in press). In spring, nocturnal migration in the Negev (southern Israel) declines less rapidly throughout the night, suggesting that in autumn birds migrating towards deteriorating habitats tend to land earlier in the course of the night, while spring migrants continue migration towards better habitats (Bruderer 1994).

Height distribution

Average and Modifications Due to Weather and Topography

The height zone in which most migrants fly comprises levels up to 4000 m. In the Swiss Lowlands, 50% of diurnal spring migration on average takes place below 400 m above ground level (a.g.l., corresponding to about 800 m above sea level, a.s.l.). The median in nocturnal migration is at about 700 m a.g.l. (1100 m a.s.l.), 90% of the migrants are found on average below 2000 m a.g.l. (2400 a.s.l.) in diurnal and nocturnal migration. The actual height distribution depends largely on the vertical profile of wind conditions (Bruderer 1971, Bruderer & Steidinger 1972, Steidinger 1972). In autumn, the height distribution of nocturnal migration is similar to spring, but diurnal migration occurs often at considerably lower heights, because the prevailing westerlies are opposing winds in autumn. Again, the distribution in single nights is influenced by the altitudinal profile of winds (Bruderer 1997b, Bruderer & Liechti 1998). Low temperatures do not prevent birds from migrating at great heights. Over Switzerland, some migration occurs regularly at heights with temperatures around -10 to -15^{0}C. In case of cloud layers at normal migratory heights, birds often concentrate above and below the clouds (Bruderer 1971). When approaching the Alps those birds which do not shift their course to fly along the Alps (see below) have to climb. While reaching the altitudes of passes or ridges they mix with birds having approached the Alps by horizontal flight at greater altitudes, thus increasing the density of migration at low levels over ground and leading to a main level

of migration at the height of the average level of passes (2000 m a.s.l.) under disturbed meteorological conditions and at the height of the main ridges of the Alps (~3000 m a.s.l.) in fine weather. Highest tracks recorded over southern Germany and northern Switzerland were 4000 to 4700 m a.s.l. (radar stations at ~ 400-500 m m a.s.l.), closer to the border of the Alps or the Jura they were 4900 to 5000 m a.s.l. (radars at ~ 500-800 m a.s.l.), above inner Alpine valleys 5500 to 5700 m a.s.l. (radars at ~ 400-700 m a.s.l.), above Alpine passes 5200 to 5400 m a.s.l. (radars at 1800 m a.s.l.). Thus, from southern Germany to the Alps, the upper limit of migration increases gradually by about 1000 m relative to sea level, while the average altitude of the surrounding terrain (hills and mountain ridges) rises from about 500 m to roughly 3000 m. Highest altitudes were, however, not recorded above the Alps, but over southern Israel (see below) and over the western Mediterranean: 5300 to 6100 m a.s.l. near Malaga, and 6200 to 6500 m a.s.l. above the Balearic Islands.

In southern Israel the wind regime is characterized by fairly stable northeasterly trade-winds below a wind-shear at 1500 to 2000 m ASL. Above this wind-shear the winds are more southerly or westerly. Due to this trade-wind regime, the altitudinal distribution

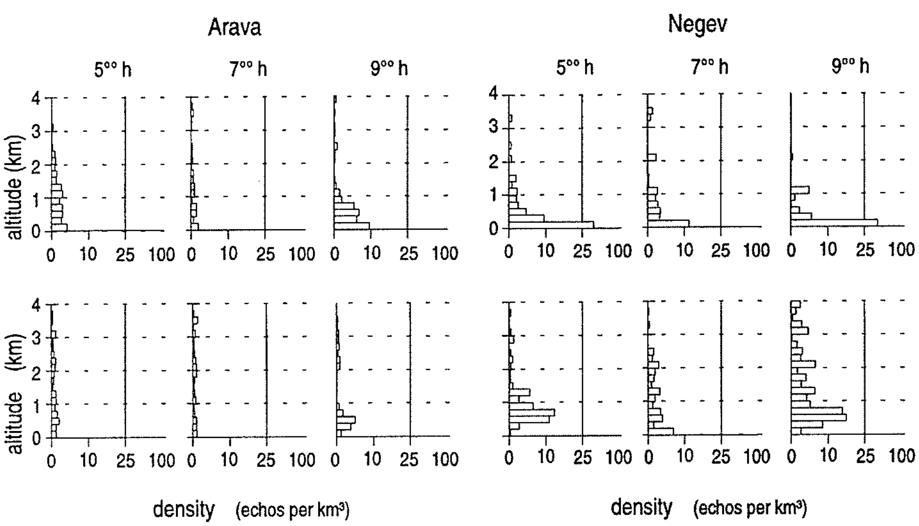


Fig. 6) Average altitudinal distribution of diurnal migration. Three measuring times (local winter time = UTC + 2 hrs) with pooled data from September/October 1991 (upper diagrams) and April 1992 (lower diagrams) for Arava (Hazeva) and Negev (Sede Boqer). Diurnal migration in the trade wind zone consists mainly of soaring birds (such as raptors and storks) and of aerial hunters (like swallows and swifts); pre-Saharan diurnal migrants among the passerines proceed only in small numbers so far south, while most trans-Saharan passerine migrants as well as waders migrate at night. The 5 o'clock measurement is before civil twilight in spring and autumn; it, therefore, contains the final phase of nocturnal migration. The 7 o'clock measurement represents an early phase of diurnal migration comprising only birds using powered flight, while in the 9 o'clock measurement increasing numbers of soaring migrants are included. The number of echos per km3 is not comparable to the number of birds/km3 at night, because diurnal echoes may comprise flocks of birds with varying numbers of individuals.

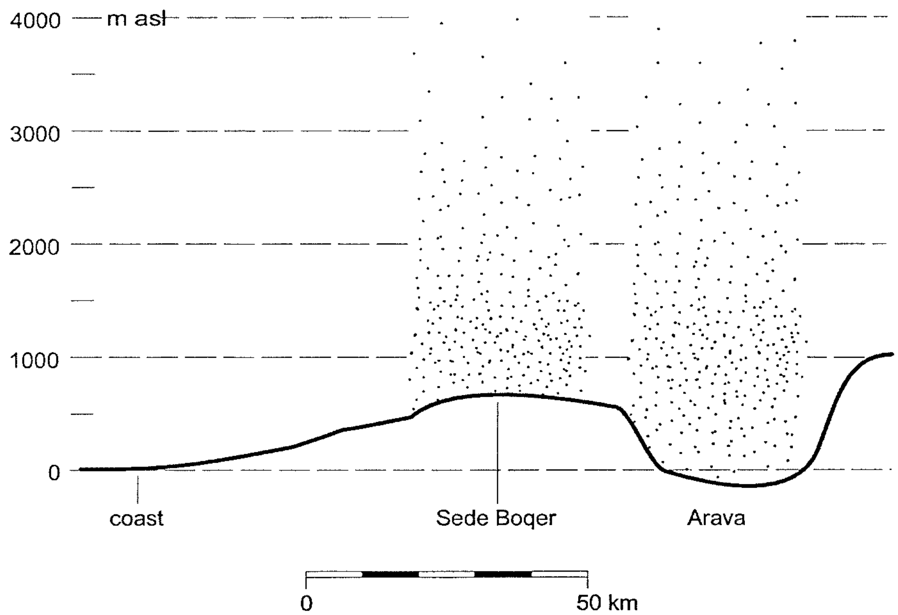


Fig. 7 (above)) Height distribution of nocturnal migration over the Negev Highlands and the Arava Valley. Note that altitudes above ground differ between sites, while altitudes above sea level are nearly equal due to similar altitudinal wind profiles (birds choosing the altitudes with best tailwind conditions).

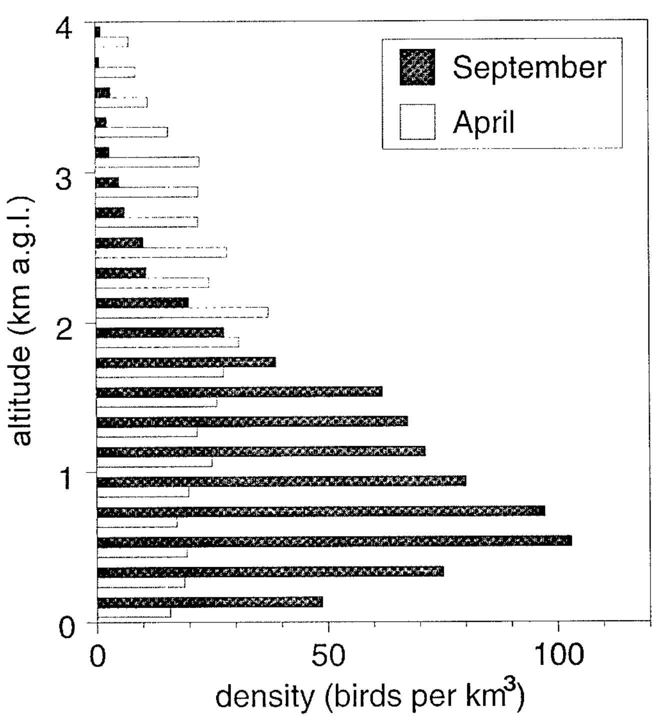


Fig. 8) *Height distribution of migration at midnight in April and September (the months with main spring and autumn migration, respectively). Most autumn migrants choose flight altitudes below the windshear of the trade wind system. In spring all migrants have to climb and descend through the north-easterly trade winds to reach the favourable anti-trades above about 1500 m a.s.l. Therefore, spring migration is more homogeneously distributed, but with an increased proportion of migrants high up.*

differs greatly between regions and seasons: On the one hand, autumn migrants fly low in the trade winds, while those in spring tend to fly high in the anti-trades, on the other hand, low flying birds have to climb when approaching the Negev Highlands and, therefore, create high densities of migrants at low levels over ground when mixing with the birds having been flying at these altitudes already before. This leads to typical distributions at two specific sites: In the Arava Valley (150 m below sea level) most autumn migrants fly below 1500 m a.g.l. (median at 1000 m a.g.l.), while in the Negev Highlands (450 m a.s.l.) the median is at 400 m a.g.l., thus, at the same height compared to sea level. In spring, the correspond-ing median heights are at about 1800 m and 1200 m, respectively (Bruderer 1992, 1994, Bruderer & Liechti 1995). Maximum heights over southern Israel are recorded for some large migrants with flapping flight (see above) which at dawn, on their northward flight, do not descend but utilize low-level jet streams, making fast progress at altitudes up to 7000 m (Liechti & Schaller in press).

Predictions of Flight Altitudes

Bruderer et al. (1995) developed a model, based on data from mid-night radiosondes, to predict the height distribution of nocturnal migrants in the Arava Valley (southern Israel). Simulations with 1000 birds choosing altitudes by means of the night's altitudinal profile of tailwind speed closely traced the observed distributions. None of the other meteoro-loical factors proved to have a relevant influence on the distribution of birds. Liechti et al. (in press), using the same data set, tested whether physiological models predicting flight ranges according to mechanical power consumption with and without taking into account limitations by dehydration would reach a higher accuracy of prediction than the simple tailwind model. The comparison showed that windprofiles, and thus energy rather than water limitations, govern the altitudinal distribution of nocturnal migrants even under the extreme humidity and temperature conditions in the trade wind zone.

Spaar et al. (in press) compared forecasts for the upper convective boundary and the strength of thermal convection (based on mid-night radiosondes) with the flight characteristics of migrating raptors in the Arava Valley. Maximum flight altitudes of raptor migration were nicely correlated with the predicted convective depth. The diurnal course of climbing rates in thermal circling was consistent with the model predictions.

Directions and Orientational Behaviour

Wind Drift, Pseudodrift and Compensation

In central Europe, migration is mainly directed towards SW; the number of S and SE migrants is very small and shows no correlation with northerly or northwesterly winds; thus, pseudodrift is negligible (Liechti 1992). Nocturnal migrants show partial compensation for wind drift. The amount of compens-ation corre-sponds to an average speed of side-winds of 2-3 m/s. If wind speed is higher, the birds are drifted off their preferred direction.

High-flying birds (>1000 m a.g.l.) maintain a heading compensating for the wind below 1000 m, i.e. increasing side wind higher up leads to increased drift (Liechti 1992, 1993). Generally, drift increases with height over ground (Bloch et al. 1981), it is most pronounced in birds flying above extended fog layers (unpubl. data). Under strong headwinds (SW, >10 m/s) many autumn migrants let themselves be drifted towards SE by shifting their headings towards S (Liechti 1993, Liechti et al. 1994a). This was already found by Steidinger (1972) who stated that compensation is reduced in opposing compared to following winds. Observations on nocturnal autumn migration at various sites in southern Germany and northern Switzerland show that the distribution of headings vary relatively little between sites and throughout the season, while the distribution of tracks shifts simultaneously at different location according to the general wind situation, mainly according to strong westerly winds, inducing drift towards S or SE. When the birds reach the northern border of the Alps and fly along or between mountain ridges, the winds and the birds become canalized to a certain extent and drift ef-fects are reduced accordingly (Bruderer & Jenni 1990, Bruderer 1996b). The proportion of downwind flights in unappropriate directions may, however, be increased at low levels along pronounced leading lines (Bruderer 1977), particularly under complete overcast (Rüsch & Bruderer 1981).

Liechti (1995) presented a model on optimisation of heading and airspeed by migrating birds in relation to energy expenditure and wind influence. Results that with decreasing distance to the goal, compensation for wind drift should be extended by adjusting heading and increasing airspeed. Regardless of their flight mechanics, birds completing their migratory journey in a few long flights should fly faster and compensate more for lateral wind drift than birds travelling in numerous short hops. Testing the model showed good correlation of measured headings and airspeeds versus predictions.

Comparison of Free-flying Birds with Orientation in Cages

Orientation cage experiments and simultaneous tracking radar studies were used to test whether bids in cages show similar orientation as free flying birds (Nievergelt et al. 1999). The prediction was that nocturnal migrants would fly offshore under good meteorological conditions, while unfavourable conditions might favour flights along the coast. Astonishingly, the free flying birds headed towards SW under overcast and clear sky, while the caged birds showed SW directions only under clear sky; under overcast conditions they showed wide scatter from W to E. Similar scatter occured when the experiments were performed late at night. In contrast, the free-flying birds shifted their flight directions towards west as night progressed to avoid flights across the sea. Flight directions observed by radar shifted slightly towards W as the season progressed owing to more frequent southeasterly winds. In the cages, however, directional preference was scattered towards SW and SE in the early migratory season and became unimodal (SW) at the peak of the season. This suggests, that nocturnal SW-migrants tested in cages in a stage of suboptimal motivation for migration show wide scatter of directions, including SE-direction. Similar scatter was observed in Reed Warblers (Acrocephasus scirpaceus) with low muscle score; only

individuals with high muscle and fat score were well oriented towards SW (Nievergelt 1998).

Reverse Migration and Retro-migration

Radar studies revealed the astonishing fact that there is very often a notable fraction of migrants flying in seasonally unappropriate directions. While earlier studies dealt mainly with hard-weather movements in spring, radar observations showed that reverse migration occurs as frequently in autumn (Bruderer 1975, 1997b). It often occurs simultaneously with normal mig-ration, but often at specific heights, with winds against the principal direction of migration, and often with other unfavourable weather conditions provoking directional scatter (Bruderer 1975). In southern Israel, reverse migration is even more pronounced in autumn than in spring, suggesting that birds in autumn are prone to return to (previously experienced) better habitats, while in spring most of them have experienced the desert before (Bruderer 1994a and unpublished data). Another explanation may be that reverse migration in autumn occurs at high altitudes (in the antitrades above the wind-shear), while in spring it takes place in the tradewinds (below the wind-shear), where birds may rather land instead of flying in unappropriate directions (Liechti & Bruderer 1995 and unpublished data).

Wind-dependent reverse migration was also observed in the Alps; an important additional facet of the phenomenon is the high proportion of waders involved in these movements, which might bring these specialized birds back to more appropriate (and probably known) resting areas in the lowlands (Bloch et al. 1981, Bruderer 1996b). On the Balearic Islands reverse migration is more pronounced than in central Europe. The proportion of reverse migration increases in the course of the night, suggesting diminishing motivation to continue flights across the sea at times when decreasing fat reserves and/or endogenous rhythms dissuade from crossing an obstacle of unknown dimensions. This increase in the proportion of reverse migrants in the second half of the night, combined with low flight levels and reduced speeds are indications of motivational conflicts between continuing migration and landing (Bruderer & Liechti 1998b). At the coast of southern Spain near Malaga axial reverse migration is replaced by a gradual shift of migratory directions towards the coast in the course of the night (Bruderer & Liechti 1998b). Such temporal coastward shifts can be observed at various other sites along the Mediterranean coasts, and include east- and westward shifts (Fortin et al. 1999). In the Swiss Lowlands there is a slight shift of directions away from the Alps in the course of the night (Steidinger 1968, Bruderer 1975). It seems that migration towards seasonally unappropriate directions is caused by endogenous or exogenous factors leading to decreased motivation for migration or, alternatively, an increased tendency to look for suitable landing areas. Under such conditions birds may increasingly tend to fly downwind and/or towards areas with potential resting areas; therefore, the directions of such movements may, but must not take place opposite to the normal direction of migration.

Winds against the seasonally appropriate direction of migration may be so strong that the migrants can make no progress or may even be blown backwards. The biologically

meaningful reaction of birds in such cases is to land; in some cases reverse migration occurs. There are, however, cases in which the urge to migrate is so strong that they continue to fly against the wind in spite of being blown backwards. This can often be observed when birds repeatedly try to cross a mountain ridge against the wind. It occurs, however, also at night and high above the ground. Bruderer (1977) mentions such cases of retro-migration, where among 2200 tracked spring migrants above the Swiss Lowlands 14 individuals were blown backwards. In an exceptional autumn night a notable proportion of migrants was observed flying tail-on through the Swiss Lowlands above a fog layer (unpublished data).

Effects of Topography and Clouds

Surveillance radar data suggest that actual migratory directions follow the bow of the Alps and thus deviate from directions expected from ringing recoveries (Baumgartner & Bruderer 1985). While birds flying higher than the main ridges in fine weather often maintain their headings, lower flying birds shift their tracks to an average of 240 in eastern Switzerland and to 220 in w estern Switzerland (Bruderer & Jenni 1990). When arriving at the first ridges of the Alps, bird migration shows a pronounced increase in the spread of directions, partly due to different flight behavi-our of low and high flying birds, partly induced by diverging directions when the birds are approaching single ridges, particularly under winds against the normal direction of migration and when flying below clouds (Rüsch & Bruderer 1981, Liechti & Bruderer 1986). Low flight levels and drift caused by opposing winds concentrate birds in Alpine valleys and passes, leading to pronounced adjustments of migratory directions to the course of the main valleys and passes (Bruderer 1978a). Generally, the influence of topo-graphy on the migrants increases with increasing headwind component, cloud cover and decreasing flight levels.

Migrating birds avoid staying in clouds. Whenever possible they fly around cloud banks; in case of extended cloud layers, they tend to stay below or to climb above (Bruderer 1980a). Individuals released inside clouds from a ballon circled around until they saw a gap below or above them and dived or climbed towards this gap (Bruderer 1977). When released on the ground under cloudy sky climbing occurred often by circling (Bruderer & Neusser 1982). Birds released in fog flew towards the next light source (e.g. into the radar tent) or towards a relatively bright surface (e.g. towards the wall of a white caravan) (unpublished data).
The flight directions taken, when released at night a few kilometers off the dark slope of a mountain ridge to the SW, were always away from the mountain and thus not in a seasonally appropriate direction. Among 19 Black Redstarts Phoenicurus ochruros released at night, two individuals (one of them twice) showed homing flights to the capturing site situated to the NE of the release site. Birds released simultaneously at an other site with no topographical obstacles to the SW were mainly oriented towards SW / SE (Bruderer & Neusser 1982 and unpublished data).

Flight Behaviour

Recording of flight paths by tracking radar has considerably improved our understanding of flight strategies, optimization of migratory flights, and flight mechanics. Echo-signatures provide information on flocking behaviour and on the wingbeat pattern of birds tracked individually. They can also be used to study flight mechanics under different environmental conditions and in different flight phases. Releasing captured birds and tracking them first visually through a telescope mounted parallel to the radar beam and then automatically by radar, has opened a new window towards flight behaviour under particular conditions.

Flying Singly or in Flocks

In daytime, most migrants fly in flocks. In passerines, waders, waterfowl, storks etc. such flocks may be considered a kind of social group, while birds of prey may aggregate because they use the same updrafts and concentrate on land briges; in areas with low density of migration they prefer to fly singly. Smaller species like some falcons and the Levant Sparrowhawk Accipiter brevipes may build up social flocks for diurnal flights and nocturnal roosting; however, when migrating at night, they are detected singly (Stark & Liechti 1993, Spaar et al. 1998).

The start of nocturnal migration often takes place in flocks; this is particularly true for waterbirds and waders. Nocturnal passerine migrants, and somewhat less also waterbirds and waders, segregate to fly singly or in very loose associations in progressing darkness. Above the Swiss Lowlands, 90% of the nocturnally tracked targets are single passerines. Most nearest neighbour distances over central Europe are larger than 50 m even in very dense migration (Bruderer 1971). Above southern Israel 50-60% are single passerines, 20-30% of the targets show continuous wingbeats. The remaining 20% are unidentifyable targets (inlcuding insects, bats and flocks of birds) (Bruderer 1994, Liechti & Bruderer 1995).

Airspeed

Bloch & Bruderer (1982) showed the distribution of airspeeds in a large sample of birds tracked on a pass in the Swiss Alps. The airspeeds of most birds were in a range of 8-18 m/s; the airspeeds indicated partial compensation for the wind vector along the flight path, thus confirming measurements by Bruderer (1971). Stark (1995) found the expected increase of airspeed with altitude in Swifts (Apus apus and A. melba) and in small passerines: i.e. in European Robins Erithacus rubecula and tendentially also in Goldcrests (Regulus spec.), but not in Songthrushes Turdus philomelos. These results confirm the findings of Liechti (1991) who found an increase in airspeed with altitude in small, but not in large passerines.

Tracking radar data show astonishingly similar airspeeds for different wingbeat categories, but explainable differences between sites (Liechti 1992, Liechti & Bruderer 1995, Bruderer 1997b). Birds with slow continuous wingbeats SC (comprising among others

waders and waterfowl, but also slower flyers such as swifts) have airspeeds of roughly 14 m/s above the Swiss Lowands (a), nearly 15 m/s above the Swiss Alps (b), and 12 to 13 m/s in southern Israel (c); the higher speed in a) and b) compared to c) may partly be due to the reduced air density, which theoretically induces an increase of speed of roughly 5% per 1000 m increase in altitude; additionally the samples from Europe include a higher proportion of ducks; besides air density the difference between a) and b) in all wingbeat classes is influenced by the selectivity of fat and long-winged long-distance migrants for flights across the Alps (Bruderer & Jenni 1990). The airspeeds of birds with fast continuous wingbeats FC (comprising among others small waders) at the corresponding sites are: a) 11 m/s, b) 12.5 m/s, c) 12-14 m/s, comprising a wider spectrum of fast long-distance migrants in Israel. The values for SI (slow intermittent flapping) are: a) 13.5, b) 14.5, c) 10.5 with a high proportion of fast-flying starlings and big thrushes in Europe, and many chats and shrikes in Israel. For FI (fast intermittent flapping, comprising mainly warblers and flycatchers) the values are: a) 11, b) 12.5, c) 11-11.5.

Peter & Kestenholz (1998) report diving speeds of Falco peregrinus (36 and 51 m/s) and F. pelegrinoides (42 and 44 m/s).
A list of airspeeds of over 130 radar tracked species (Bruderer & Boldt in press.) shows that theoretical predictions of maximum range speed (Vmr) overestimate the airspeeds of large birds, suggesting that with increasing size, large birds in powered flight may increasingly shift from speed of maximum range towards speed of minimum power. The high speeds of small birds, on the other hand, suggest that reduced profile drag in bounding flight allows these small birds to fly faster than theoretically predicted (without making allowance for bounding flight).

Vertical Speeds

Climbing and descending birds are found in similar proportions throughout the night. Only in the first hour after dusk is there a surplus of climbing birds, while in the hour before dawn the proportion of descending birds is slightly increased. In Israel the proportion of climbing birds during the first hour of the night is different between autumn (60% climbing) and spring (75% climbing), because in spring birds have to climb above the trade winds. The average climbing rates of all birds with positive vertical speed throughout the night is 0.5 m/s in autumn and 0.9 m/s in spring (maxima up to 4 m/s) (Bruderer et al. 1995b). Final descent may be very steep and fast, thus usually escaping detection by the tracking method.

Flight Mechanics of Small Birds with Intermittent Flapping

The flight of small and medium-sized passerines is characterized by alternating flapping and pausing (or resting) phases. Medium-sized species (thrushes, starlings) and hirundines may keep their wings partially spread during the pauses (partial bounding), while smaller species close their wings completely, maintaining high speed while losing height in undulating or bounding flight.

Stark (1995) emphasizes high individual variation in all measurable parameters (wingbeat frequency, length of beating and resting phases, horizontal and vertical speed). Variation is extreme in released birds; but even in free flying birds a variation of ± 10% or even 15% in wingbeat frequency seems to be quite normal. In most species vertical speed is controlled by varying the length of beating and/or pausing phases (see also Bloch et al. 1981, Renevey 1981). Slight variations in wingbeat frequencies with vertical speed are inconsistent between species. The European Robin Erithacus rubecula seems to increase horizontal speed by higher wingbeat frequency and longer pausing phases, flexing the wings completely during pausing phases. In species keeping their wings partly spread during pausing phases (e.g. thrushes, swifts), there was no consistent variation in the measured parameters, suggesting that factors not measured by radar may be important. Higher flight altitudes are correlated with increased airspeeds and higher wingbeat frequencies in some but not in all species studied (Stark 1995).

In a wind-tunnel and tracking radar study L. Bruderer (unpubl. thesis 1999) shows that Swallows Hirundo rustica and House Martins Delichon urbica keep their wings partly open during pausing phases, the degree of flexing depending on speed. Using their wings to produce residual lift during pausing, they avoid the undulating flight paths of other small passerines. The pausing phases are not interspersed regularly between burst of wingbeats as in other passerines, but are usually parts of the wingbeat cycles, thus leading to a wide variation of effective wingbeat frequencies. The effective wingbeat frequency varies with horizontal and vertical speed in a systematic way, suggesting a high number of wingbeats per unit time when a high power output is needed (e.g. at very high or low speeds or when climbing).

According to theory, the speed of migration is not the one with minimum energy consumption per unit time, but the one with minimum energy consumption per distance covered. Tracking radar studies on Common Swifts Apus apus proved the existence of these two distinct flight speeds. They used the speed of minimum power (around 23 km/h) for nocturnal resting flights and the speed of maximum range (around 40 km/h) for migratory flights (Bruderer & Weitnauer 1972).

Radar data provide also support for the prediction that the speed of maximum range (Vmr) varies with wind, because maximum range can be attained at slightly reduced airspeed in tailwinds and requires increased airspeed in headwinds (Bruderer 1971). Large sets of radar data allowed to test an improved theoretical model including sidewinds instead of being restricted to direct head and tailwinds. Vmr not only depends on the effect of wind on the groundspeed of the birds but also on its angle of compensation for sidewinds. As a result, optimal flight speeds are higher in sidewinds than in tail- or headwinds with the speed increment caused by wind (Liechti 1993, Liechti et al. 1994).

Flight Mechanics of Birds with Continuous Flapping

Continuous wingbeats are used by a large variety of taxonomic groups and size classes (Bruderer 1994, Liechti & Bruderer 1995). Birds as large as swans, geese, ducks, and

herons as well as small birds like small waders fly large distances by beating their wings continuously. Even large passerines like crows use continuous flapp-ing in sustained level flight. Only in fairly steep or extended descending flights or in considerable updrafts are these birds interrupting their wingbeats. As continuous wingbeats would not allow to control vertical speed by the variation of pausing and flapping phases, wingbeat frequency was the obvious candidat to be responsible for such manoeuvers. This was confirmed in the case of a species with low wing-loading (Corvus corone) which varied its vertical speed from -1 m/s to +2 m/s by varying the wingbeat frequency (average 3.6 Hz) over a range of 1.5 Hz (Althaus & Bruderer 1982). However, Renevey (1981), analysing tracks including horizontal as well as climbing or descending parts of continuously beating nocturnal migrants, could not find systematic variation in flapping frequencies according to vertical speed. They seem to use other means (e.g. angle of attack or amplitude of wingbeats) for moderate climbing and descending; in step descending flights waders and ducks intersperse gliding phases between bursts of wingbeats (Kestenholz 1995).

Soaring Birds

In a review on flight behaviour of migrating raptors Spaar (1999) summarized the results of previous research, confirming that in soaring-gliding flight many species maximize cross-country speed by adopting thermal depending gliding airspeeds. Inter-thermal gliding airspeed decreases with increasing tailwind components and allows the birds to reduce time-consuming thermal circling by prolonging the range of inter-thermal glides. Besides circling in thermals, straight line soaring is frequently observed in large species. During inter-thermal gliding, mean airspeed of many raptor species is positively and gliding angle negatively correlated with body mass, the larger species compensating power constraints due to size by better gliding performance. Large species such as eagles and buzzards show soaring-gliding flight during more than 95% of their migratory flights, while smaller species like harriers, sparrowhawks, and falcons show increasing proportions of flapping, in spite of the fact that they also prefer the energy-saving soaring-gliding strategy in good thermal conditions. The larger the raptor species the more the birds optimize their flight behaviour by adjusting gliding speed to the actual climbing rates achieved under the given conditions (Spaar 1997). Harriers proved to be just in the transitional size category where the largest species is closer to the typical soaring migrants, maximizing cross-country speed when soaring and gliding, whereas the smaller species are less adapted to this optimal use of thermals, but efficiently combine different flight styles (Spaar & Bruderer 1997). White Storks show less adjustment of gliding speed to climbing rate, suggesting that for these social birds it is more important to keep contact with a flock of conspecifics than to optimize flight performance (Liechti et al. 1996a).

Flight altitudes of larger soaring species, such as Aquila, Accipiter and Pernis reflect the local and diurnal variation of convective activity. Average climbing rates in thermals range from 1.5 to 2.1 m/s in Israel; highest climbing rates, occasion-ally up to 5 m/s, are reached around noon. The climbing rates are not significantly different among species, but differ

according to atmospheric conditions (Spaar 1996, 1997). Honey Buzzards Pernis apivorus e.g. have average climbing rates of 1.67 m/s in Israel and 0.44 m/s in Switzerland, where they compensate lack of thermals by additional wing-flapping at low flight levels (Bruderer et al. 1994).

A case study on the Steppe Buzzard Buteo buteo vulpinus showed adjustment of interthermal gliding aispeed according to actual climbing rate in thermal circling. By optimizing gliding airspeed the birds maximized cross country performance relative to the air. Yet, lower sinking rates due to extended updrafts allowed many birds to achieve higher cross-country speeds than predicted. In addition, the birds increased their gliding airspeed with decreasing tailwind. The average climbing rate was 2 m/s, including very low rates early in the morning and towards evening. Average cross-country speed was 9.8 m/s (Spaar & Bruderer 1997).

Similar to the Steppe Buzzard also the Steppe Eagle Aquila nipalensis increased gliding airspeed with increasing thermal convection and in opposing winds. Straight line gliding was more frequent than in the Buzzard. Therefore the mean cross-country speed was higher (12.4 m/s) than in the latter, while the mean climbing rate over the whole diurnal cycle was very similar (1.9 m/s) (Spaar & Bruderer 1996).

Levant Sparrowhawks Accipiter brevipes dispose of an extremely flexible migration strategy which includes nocturnal activity: (a) when good thermals are available, the predominant flight style is soaring-gliding; (b) under such conditions they maximize cross-country performance relative to the air according to optimal flight theory, and thus minimize time per distance travelled in an overall cheap flight style; (c) they can also use flapping-gliding flight when thermal activity is low, and thus are able to extend the time available for migration; (d) high numbers of Levant Sparrowhawks have been tracked at night, flying by typical flapping-gliding flight at significantly higher altitudes than in diurnal flights. The use of flapping flight at the edges of the day, and nocturnal flights indicate time instead of energy minimization (Stark & Liechti 1993, Spaar et al. 1997).

Migration Across Barriers

The Area of the Alps

Nocturnal Migration

Due to basic directions of nocturnal autumn migration around SW (on average 230) in central Europe, only a small fraction of this broad front migration approaches the Alps in fine weather with weak winds. The low flying birds of this small part slightly shift direction according to the bow of the Alps and the Jura mountains (Baumgartner & Bruderer 1985, review Bruderer 1996b). Important deviations from the basic direction are caused by the frequent westerly winds which drift the birds towards S and SE, and thus towards the Alps (Bruderer & Jenni 1990). Along the Alps the winds as well as bird migration are funnelled regionally by the mountain ranges and locally by single ridges as far as they are below the ridges. Local deviations as well as the difference between low and high flying birds lead to wide scatter of directions at the border of the Alps (Bruderer 1982, Liechti & Bruderer 1986). High-flying birds have more southerly directions

already above southern Germany; they are exposed to higher wind speeds and increased drift (Bruderer & Jenni 1988, 1990). Birds above the Alps have higher airspeeds than those above the lowlands at the same altitude (Liechti 1992). Coordinated moon-watch operations in a wide area N and S of the Alps, showed that even in good weather, with moderate opposing winds restricted to altitudes above 1500 m a.s.l., the concentration along the Alps may be considerable, the density of migration doubling from northern Switzerland to the border of the Alps and being reduced to 20% to the S of the Alps. The directions S of the Alps are widely scattered, although mainly oriented towards W above northern Italy, shifting SW or S along the southward-bending ranges of the Mediterranean Alps (Liechti et al. 1995a, 1996b,c).

Soaring Birds

Schmid et al. (1986) showed a striking coincidence in migratory directions of Common Buzzards Buteo buteo buteo with nocturnal passerine migration: Buzzards approach Switzerland with directions around 229 , corr esponding to directions expected according to ringing recoveries. In the eastern lowlands the average directions is 239 , in the w estern Lowlands 219 . S parrowhawks Accipiter nisus, often using flapping flight in addition to soaring-gliding migration, appear in greater numbers on Alpine passes than Buzzards. Buzzards, depending on soaring-gliding flights during migration, have restricted capacity to cross the Alps, this capacity decreases with decreasing thermal activity in the course of autumn. Bruderer & Jenni (1990) showed that the tendecy to avoid crossing the Alps by flying along the mountain ranges increases in relation to the proportion of soaring compared to flapping-gliding flight in 11 raptor species.

The Eestern Mediterranean

Autumn Migration

A recent summary (Bruderer & Liechti 1999) suggests broad-front migration on a NE-SW axis across central Europe, with declining density to the SE. Directions shift southward along the Atlantic coast, are more westerly along the northern and southern borders of the Alps as well as along the French Mediterranean coast, and shift to SW or even SSW over the central parts of the Iberian Peninsula. Contributions to this general view can be derived from an infrared transect along the European coast of the western Mediterranean, showing important variation of directions in accordance with the geographic situation, and from various radar- and moon-watch data (Rivera & Bruderer 1998). Tracking radar studies show mainly southward directions on Mallorca and a shift of directions during night from SSW to W at the Andalusian coast (Bruderer & Liechti 1998). The infrared data collected along the Mediterranenan coasts confirm this nocturnal coastward shift for various sites (Fortin et al. 1999). Southward or SSW-ward migration occurs to the south of the Massif Central (France) and at the Spanish Costa Brava (along the partially southward leading coast and then towards the Balearic Islands), and generally across the southern coast of Spain (towards Africa). Concentrated SW-migration follows the

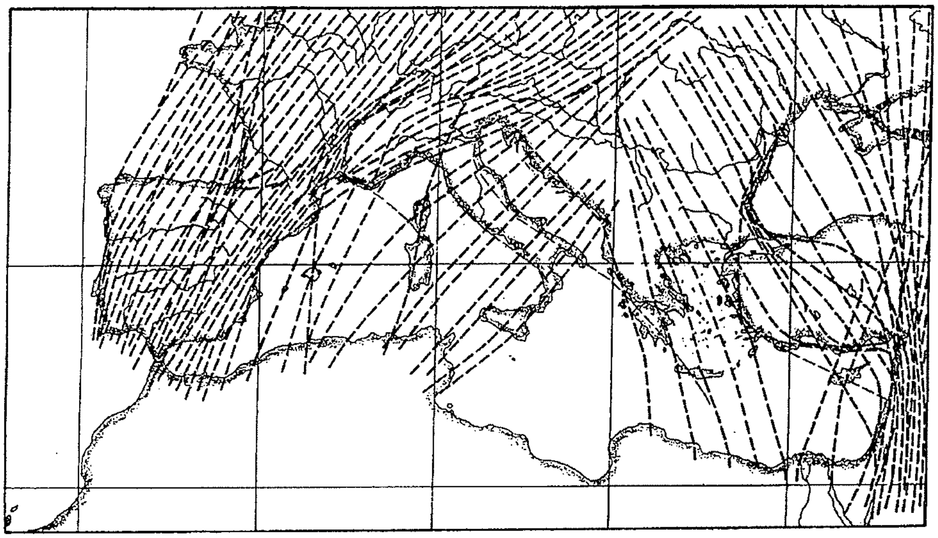


Fig. 9) Map of suggested directions and concentrations of migratory streams in Europe and the Middle East, primarily based on our own radar, infrared and moon-watch data, bridging the gaps between this punctual information by inference from other sources (first published in Bruderer & Liechti 1999; see there for details on sources).

SE-coast of Spain (Rivera & Bruderer 1998). A concentration of migrants is also assumed along the W coast of the Iberian Peninsula, due to an influx of birds from NNE and southward bending directions of birds from NE, while densities of migration across the western part of the Mediterranean Sea seem to be reduced (Bruderer & Liechti 1999). New moon-watch data confirm that the general directions of nocturnal migration lead to a convergence of migratory streams over the Iberian Peninsula. This general funnelling of directions is increased by deviations observed in coastal areas, particularly in upper Italy and southern France (Bruderer & Liechti 1999). An infrared transect to the N of Gibraltar confirmed the general SW/SSW flow of migration in southern Spain. Additionally the infrared observations suggest that diurnal and weather-dependent shifts in directions may lead to a slight and variable concentration of nocturnal migrants towards the Strait of Gibraltar (Bruderer & Liechti 1999).

The diurnal pattern of migration at Malaga in September is characterized by a sharp decrease in density after an impressive take-off phase. This implies a high concentration of trans-Saharan migrants close to the coast. This concentration is not only caused by premature landing of birds approaching the coastal area late at night, but additionally by birds returning from the sea towards morning (Bruderer & Liechti 1998), possibly also by birds waiting for optimal weather conditions. The decrease in October was less pronounced: by shifting along the coast and continuing migration along the coast, the pre-Saharan migrants in October remained airborne for a longer time, but accumulated along the coast to equal numbers as the trans-Saharan migrants in September (Bruderer & Liechti 1999).

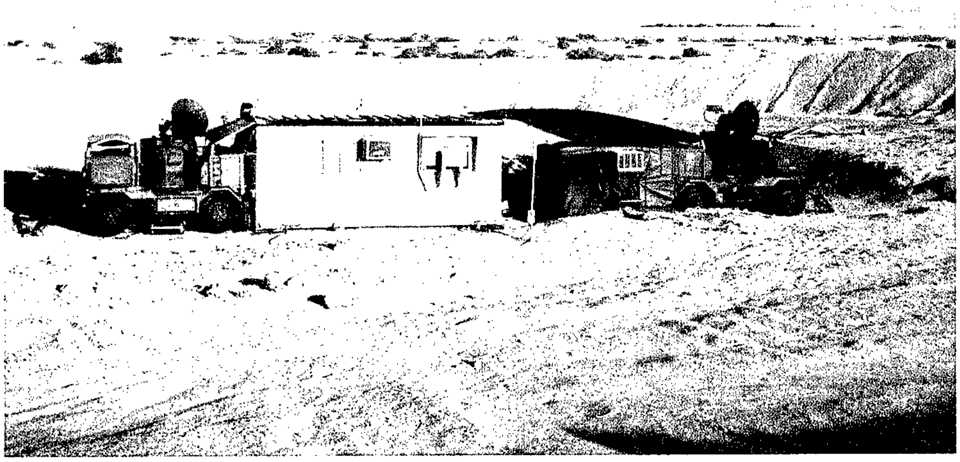


***Fig. 1a)** The radar site in the Arava Valley near Hazeva 150 m below sea level (autumn 1991, spring and autumn 1992). In the background the Jordanian mountains. A dam of sand protects the two radars against ground clutter.*

***Fig. 1c)** Computer screen showing (on the left side) the horizontal (red) and vertical (blue) projection of the flight path of an automatically tracked small wader. The actual flight altitude was 1669 m a.g.l., the distance from the radar 3296 m, the wingbeat frequency 13 Hz, the horizontal speed 36 km/h (as indicated in the text windows). The lowest two windows show the echo signature (wingbeat pattern) of the bird. In both bottom windows one second comprises the interval between two full blue lines. Continuous flapping is typical for waders and waterfowl in horizontal flight.*

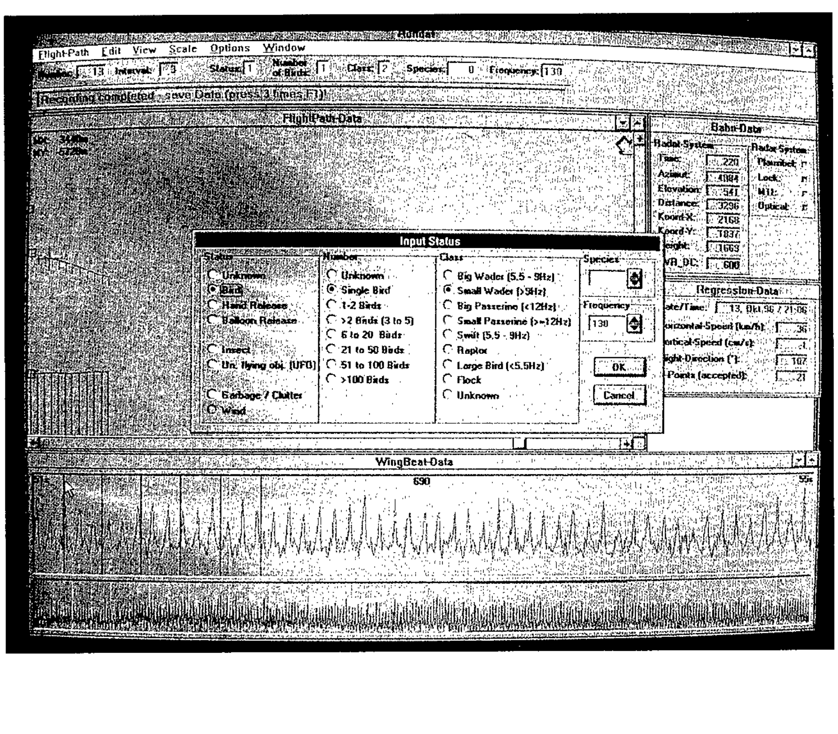
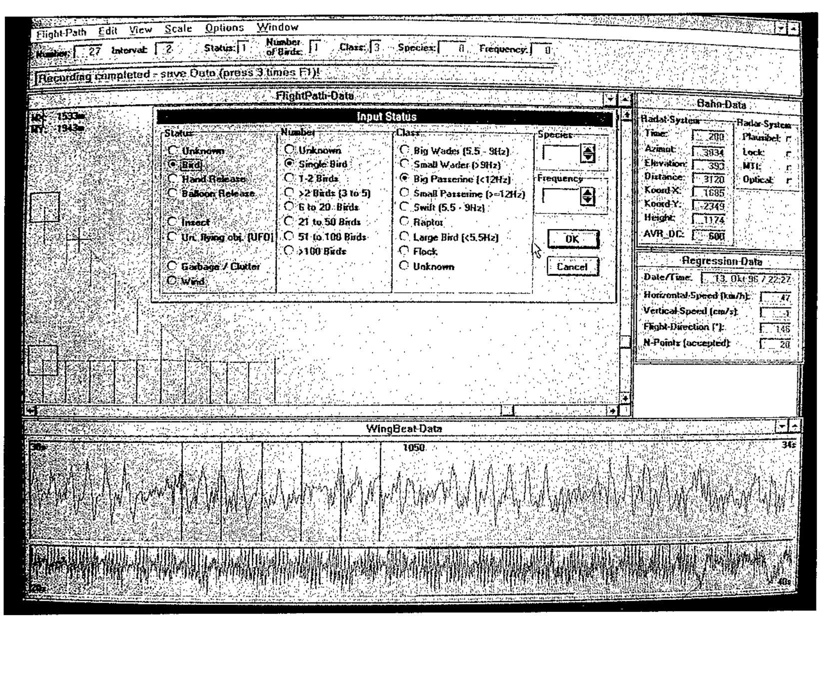


Fig. 1b) *The Swiss Bird Radar Team on the "Superfledermaus" tracking radar at the Arava site in autumn 1991. From left to right (standing) Bruno Bruderer, Christian Bruderer, Dieter Peter, Thomas Steuri, Matthias Kestenholz, (sitting) Felix Liechti, Herbert Stark.*

Fig. 1d) *Same presentation as in Fig. 1c, but the scale of the flight path is doubled and the echo signature consists of bursts of wingbeats and intermittant pausing phases typical for the bounding flight of passerine birds. The actual height was 1174 a.g.l., the distance from the radar 3120 m; the wingbeat frequency was not yet cacluated by the computer (according to a fast-Fourier-transformation) but can approximately be counted within the two bottom windows, resulting in 10 to 11 Hz, thus indicating a relatively large passerine.*



The diurnal pattern of late autumn migration on the southern tip of Mallorca reflects the passage of migratory waves having departed from various parts of the European coasts. Interestingly, the volume of departures from the island was about 75% of that at the Malaga coast. As pre-Saharan migrants may show increased flexibility with respect to local shifts in direction (see above) they might be funnelled over the island towards its southern tip. On the other hand Bruderer & Liechti (1999) hypothesized an increased propensity of pre-Saharan migrants to cross the Mediterranean Sea compared to trans-Saharan migrants. If this paradox proves to be true, a possible explanation may be that the Mediterranean Sea with about 500 km width may be overflown even with limited fat reserves, while crossing the Sahara is a bold venture requiring good wind conditions in addition to enormous fuel reserves. Following the land bridge allows refueling until immediately before the desert crossing and offers improved possibilities to choose optimal weather conditions for the desert crossing.

Spring Migration

Infrared observations of spring migration at the Andalusian coast show arrivals of birds from North Africa which are roughly half of those observed at Cape Trafalgar (Bruderer & Liechti 1999). Observations to the east of Toulon show important streams of migration arriving in southern France from the Costa Brava (on a WSW-NNE axis), while only weak migration (about one third of that at the Andalusian coast) approaches from the Balearic Islands (Rivera & Bruderer 1998). It seems that Toulon is already to the east of the stream of birds crossing the Balearic Islands, because in the Camargue area considerable arrivals from S, SSW and SW are reported (Bruderer & Liechti 1999). Spring migration on Mallorca is mainly towards N (Costa Brava), but with a notable proportion towards NE (Camargue area) (Bruderer et al. 1996). Our radar data confirm that from late March to late May the density of migration across the Mediterranean basin between Algeria and France is at least two to three times lower than that across the Iberian Peninsula (Bruderer & Liechti 1999).

Southern Israel

The Negev in southern Israel is situated in the transitional zone between the Mediterranean region and the Sahara. Observations in this area show the behaviour of migrants just after the Sahara crossing in spring and of birds approaching this hugh ecological barrier in autumn; this allows important conclusions about desert crossing.

Nocturnal Migration

A hypothetical map of nocturnal migration over the southern half of Europe and the Mediterranean Sea (Bruderer & Liechti 1999) suggests relatively weak SE migration across the eastern Mediterranean, moderate movements across Greece and Turkey, but high density N-S movements along the eastern edge of the Mediterranean Sea, resulting from converging streams of migrants from NW, N and NE. In southern Israel average

directions are mainly N-S: in the Arava Valley 190 in autumn and 4 in spring, in the Negev Highlands 193 and 13 , respectively. Slight differences between the directional distributions of birds above the Negev and the Arava can be attributed mainly to winds and local topography (Liechti & Bruderer 1995). Tracks and headings of different wingbeat classes do not differ significantly, except that birds with passerine-type flight and low wingbeat frequencies had more westerly directions in autumn and more easterly directions in spring.

The main factors governing migration in this area are the desert conditions and the trade wind system. Summarising the main features according the chapters on flight behaviour above, leads to the following conclusions: 1) Migratory intensity is less dependent on weather conditions than in temperate areas, because the birds can find good wind conditions by choosing appropriate flight levels; 2) Reverse migration is less frequent in birds coming from the desert areas to the South in spring compared to birds approaching from the Mediterranean zone in autumn; 3) Migratory intensity declines earlier in the course of the night in autumn, when the birds are flying towards deteriorating habitat, compared to spring. 4) The nocturnal schedule of migration is influenced by the available resting habitats, the passage of nocturnal passerine migration starting earlier in the Negev highlands compared to the Arava Valley, where passerines find less adequate resting habitat than in the hills and wadis higher up.

Diurnal Migration

It is only a minority of trans-Saharan migrants with flapping flight migrating in daytime. The main exception are those adapted to aerial hunting in daytime, like the swallows, which are able to feed en route. Most of the insectivorous passerines as well as waders have less variable flight capacities to cope with turbulent air, and are forced to feed on the ground. Large birds depending on soaring-gliding flight, on the other hand, have to fly during daytime and to avoid flights across large water surfaces in order to profit from thermal updrafts. Our quantitative methods are not very reliable with respect to diurnal migration, because many birds fly in flocks in daytime. Large numbers of birds may be combined into one echo, the number of recorded echoes may be very low. Therefore, our observations on diurnal migration concentrated on soaring birds and were mainly based on tracking data (see above). Quantitative data on the temporal course of diurnal migration were only analysed for the purpose of an environmental impact study in southern Israel (B. Bruderer, T. Steuri & F. Liechti 1992 unpubl. report). The number of echoes was in the order of 1 to 10% of those in nocturnal migration. The relative diurnal variation shows that up to about half an hour before sunrise the number of echoes was still increased, probably by some nocturnal migrants on landing flights and by some diurnal migrants departing singly. Lowest densities occured around sunrise, probably because all the nocturnal migrants had landed and diurnal migrants had either aggregated in flocks or were not yet fully active. Highest densities were reached 3 to 4 hours after sunrise, when not only the swallows were most numerous but also the activity of thermal soarers increased. Towards

noon, migratory activitiy of flapping fliers decreased, while soaring migrants continued, some of them until sunset.

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Review of 100 Years of Military and Civilian Bird Strikes

John Thorpe
Brackens, Chapel Road, Smallfield, Surrey RH6 9JH, UK

Abstract

The Paper provides brief highlights of bird strikes to military and civil aircraft since the first reported strike in 1904 and the first fatal bird strike accident in 1912. Since then Richardson (1) reports that military aircraft in Europe and Israel have suffered at least:

- 168 aircraft losses
- 34 aircrew killed as well as 3 civilians on the ground

Civil aircraft world wide have suffered:

- 32 fatal accidents killing 191 people
- Destruction of 55 aircraft with executive jets being particularly vulnerable

Key Words: Statistics, Civil Aviation, Military Aviation

(This Paper is the work of an individual author and may not reflect the final views of the UK Civil Aviation Authority)

Introduction

Over 50 civil aircraft have been destroyed with the loss of 190 lives as a result of colliding with birds or attempting to avoid them (Ref 1). The accident resulting in the greatest number of fatalities was the Lockheed Electra in Boston (Starlings Sturnus vulgaris, 80g) on 4 October 1960 which killed 62 people. This accident was the result of bird ingestion into three engines. Multiple bird engine ingestion is still regarded as the major threat for civil aviation (Ref 2).

Up to and including 1994, over 170 European and Israeli military aircraft have been destroyed as a result of collision with birds with at least 34 occupants and 3 civilians on the ground killed (Ref 3). Most were single or twin engined fighter or attack aircraft. At least two cases were multiple engine ingestion in four-engined aircraft:

1. A Nimrod maritime reconnaissance aircraft in 1980 making an early morning take-off at Kinloss in Scotland after collision with Black-headed and Common gulls (Larus ridibundus and Larus canus, 275g and 420g) resulted in 2 deaths.

2. A non-fatal over-run as a result of a suspected gull ingestion in 1976 by a Victor flight re-fuelling tanker at Marham, Norfolk, UK.

3. Although a B1B bomber was lost in 1987 in Colorado, killing 3 of the 6 crew,

the cause was a structural penetration which ruptured fuel and hydraulic lines resulting in an intense fire. This was during a low level training flight and thus not associated with aerodrome problems. The bird was an American White Pelican (Pelecanus erythrorhynchos, 7.3g, 16 lb).

In addition there have been many losses of US military aircraft, some in Europe and some in more recent accidents described later.

The Threat

4. The first recorded bird strike was on 7 September 1905 when Orville Wright was flying near Dayton, Ohio. He twice ran into a flock of birds one of which fell on top of the upper wing.

5. However, the first fatal bird strike accident was in 1912, involved Cal Rogers, the first man to fly across USA who was killed at Long Beach in California. A Gull lodged in flying controls of the Wright Flyer. Birds were a problem right at start of aviation - and the current major threat at the time was gulls.

6. During WW2 there were at least six fatal accidents in the SE Asia area to UK Royal Airforce aircraft due to bird strikes, including Hurricane, Spitfire and Mosquito. Also the United States Air Force in the Pacific suffered more damage due to bird strikes than to enemy action.

7. The first fatal accident to a UK Royal Airforce jet powered aircraft is thought to be a Canberra twin engined bomber in 1953, the aircraft type is still in service 45 years later.

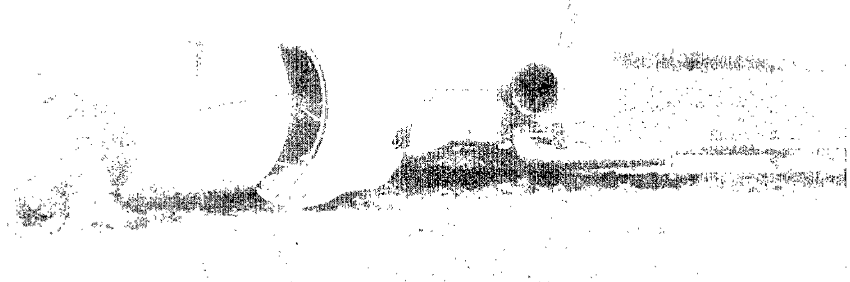
8. In 1975 a DC10 on take-off from Kennedy Airport 1975 ingested gulls including Great black-backed (Larus marinus, 2kg) into engine 3. Uncontained failure, wing tank ruptured at V1 decision speed. Abandoned take-off on wet runway, just stopped at far end on high speed turn-off. 139 on board evacuated successfully, all were airline employees who knew procedures.

9. Nearer to home, a B737 was doing touch and goes during crew training at Gosselies in Belgium, it ingested a Wood pigeon (Columba palumbus, 465g) in one engine, suffering such a severe loss of acceleration that it felt as though both engines had ingested birds. Take-off abandoned well beyond V1 - over-ran across main road into industrial estate, burnt out. The three crew escaped. Just one bird had written off a $20 million aircraft.

10. A BAe 125 which on take-off from a UK airfield lost both engines due to ingestion of Lapwings (Vanellus vanellus, 215g). Force landed straight ahead, unfortunately by a million to one chance it hit a car on the road at the end of

the airfield, killing the lady driver and five children. Three of the children were families of pilots and ATC staff on the airfield. On the day in question the Lapwing distress call tape was broken. It is important that adequate spares are available.

11. Norwegian Jet Falcon at Norwich airport after ingesting gulls. The aircraft force landed in the open fields near the airport. All occupants escaped without injury except the cabin attendant who was standing on the flight deck on take-off. As a result the insurers of the aircraft sued the insurers of the airport for their loss. After a week-long UK High Court hearing, the judge in his summation said that no matter what you do you will not prevent all bird strikes, however you must take reasonable precautions and these reasonable precautions are currently detailed in a CAA Publication CAP384, "Bird Control on Aerodromes" (Ref 4). The fact that the airport authority knew from the bird strike record that there was a hazard, from the tower log that there were birds on the airfield, and that they had no system in place to deal with them, meant that they were negligent. It had also been a factor that Air Traffic Control were unable to see the airfield clearly because the tower windows were not double glazed, there was rain on the outside and condensation on the inside. The judge said that pilots had their own job to do when taxying, such as controlling the aircraft, completing check lists, etc. and were not responsible for checking the runway state. As far as the CAA were concerned this was an excellent judgement because it showed very clearly where responsibilities lay.



12. A BAe 146 was involved in a night-time parcel flight from Genoa in Northern Italy. This aircraft, because it is very quiet, is used for these sorts of operations. At rotation the aircraft ran through a large flock of gulls, one engine over-temperatured and had to be shut down and the other 3 engines were surging and losing power. It limped to 1,000 ft to complete a circuit and return.

Inspection of the aircraft revealed all four engines needed to be changed and two of the engines had core damage as well as fan damage.

13 ...the aircraft itself suffered 54 bird impacts, in addition to the engine damage. There was extensive denting of the engine cowling.

14. ...the whole airframe was covered with blood and guts and cleaning it was a long job.

15. ....the culprit here was the Mediterranean Herring Gull (Larus argentatus, 1.0kg) which is very similar to the UK Herring Gull excepting that the UK one has pink legs instead of yellow legs.

16. The interior of the first class area of a Boeing 747. A lady passenger was sitting in the left-hand front seat during a night departure from Heathrow for New York and at about 4,000 ft, somewhere over the Brent Cross area of North London, there was a sudden bang and she found herself covered in blood. There is a story that she had a babe in arms on her lap and had hysterics because she thought the baby had exploded! In fact it was a bird strike, in this case a Lapwing at night over North London.

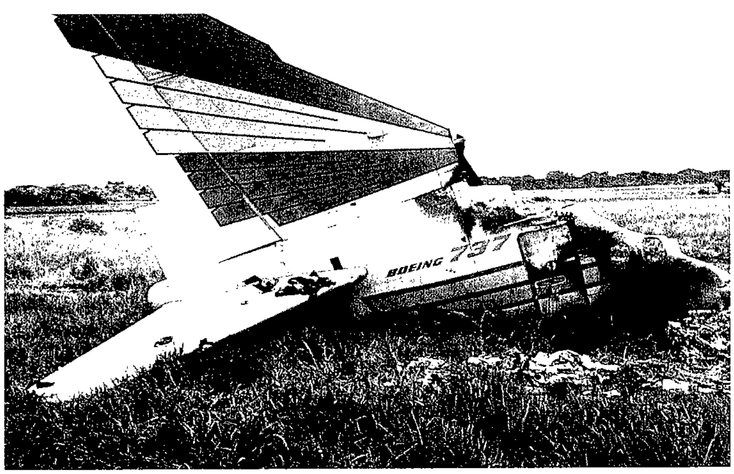
17. Impacted on the top right-hand corner of the cabin window, pushed against the seal between the two layers and broken the inner one allowing the remains to squeeze through the gap and over the unfortunate passenger. This is known to have happened at least twice previously.

18. ....the tail plane damage on the 747 was quite severe and the engineers thought that it had hit large birds but the aircraft had been at climb speed of 240 kts and the V2 law applies. A small increase in speed results in a big increase in damage, most people are used to seeing damage in the circuit or approach where speeds would be 140 to 160 kts, the different effect is very marked.

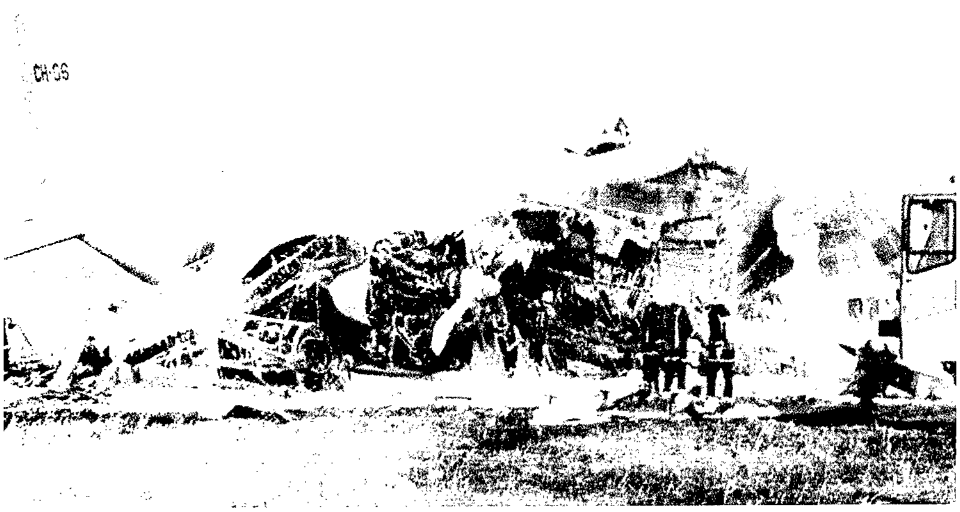
19. In 1989 at about 6 am a BAe Jetstream commuter airliner was descending into Madison Airport, Wisconsin USA and at 4500 ft and 230 kts struck a flock of seven or eight Canada Geese (Branta canadensis, 3.6kg). Both wings had 18-20 inch holes through the main spar with top and bottom angles destroyed. The tail planes were badly buckled and torn. The pilot reported there were no handling difficulties. It needed a new right-hand wing.

20. On some, generally older, advanced military training aircraft, windshields are not up to the latest technological standards and pilots are vulnerable to severe eye damage. The importance of the use of polycarbonate visors is emphasised.

21. In civil flying about 85% of strikes are in the airport area, but in military flying 70% of strikes are away from the airfield during the high speed portion of the flight.

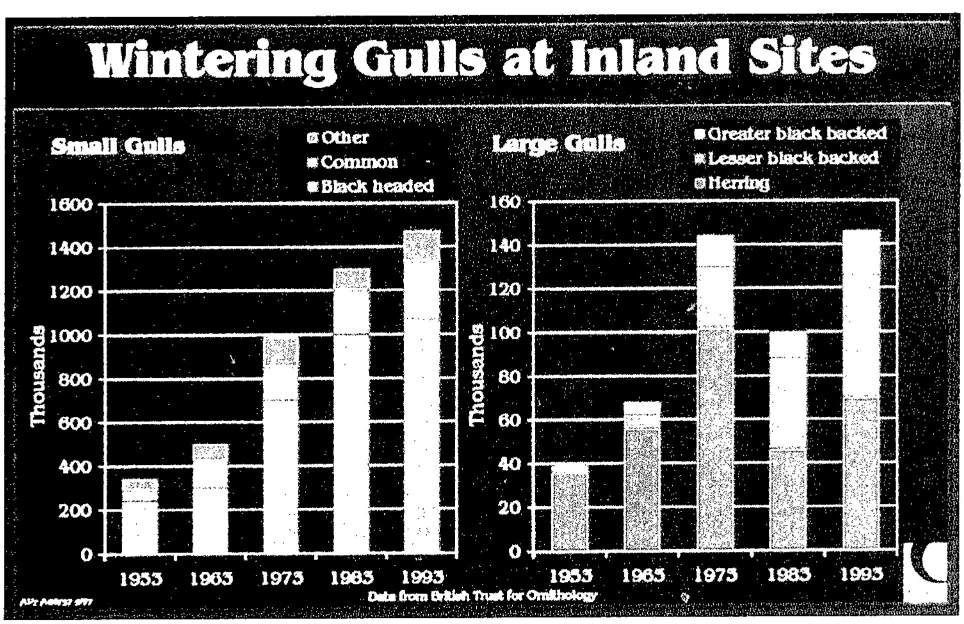


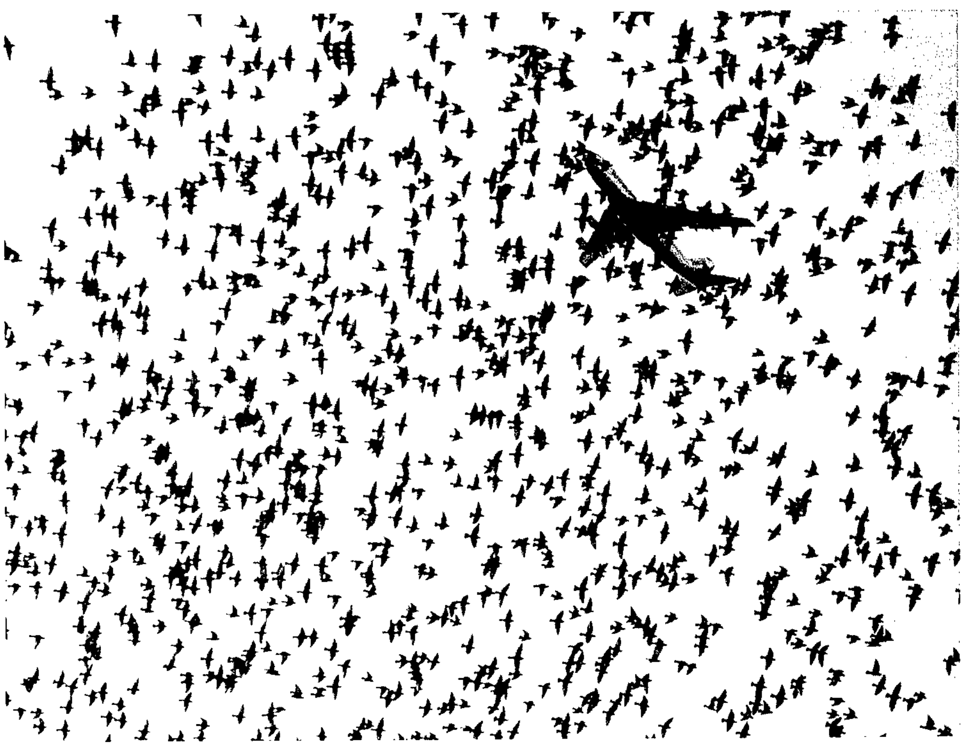
Remains of the Boeing 737 that collided with a flock of pigeons and crashed on 15 September 1988, in Ethiopia. 35 of the 104 passengers were killed.



15/7/96 A Belgian Air Force C-130 collided with starlings in Eindhoven, The Netherlands. Thirty-Five people were killed.

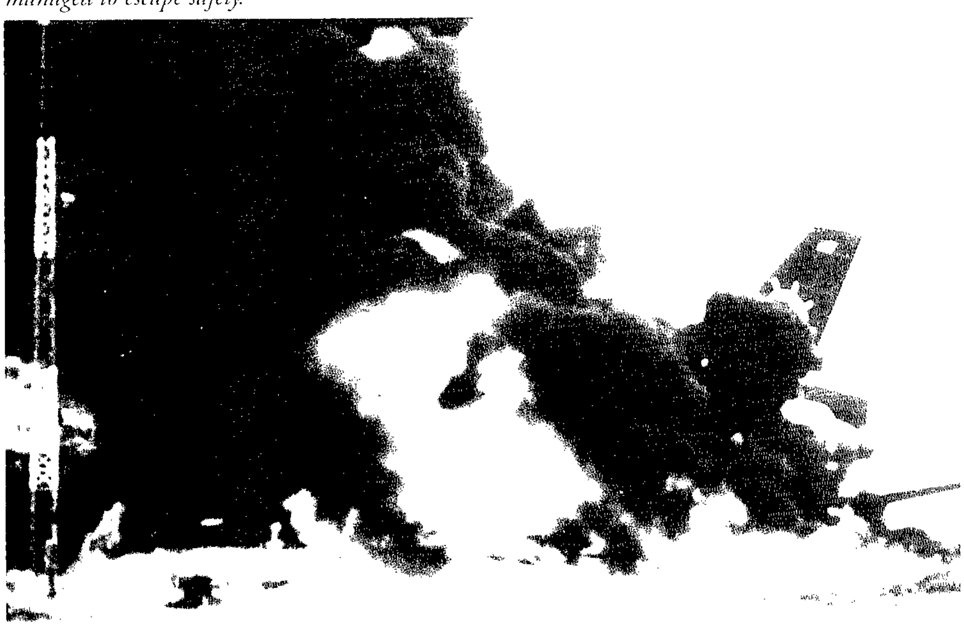
UK wintering Gull populations

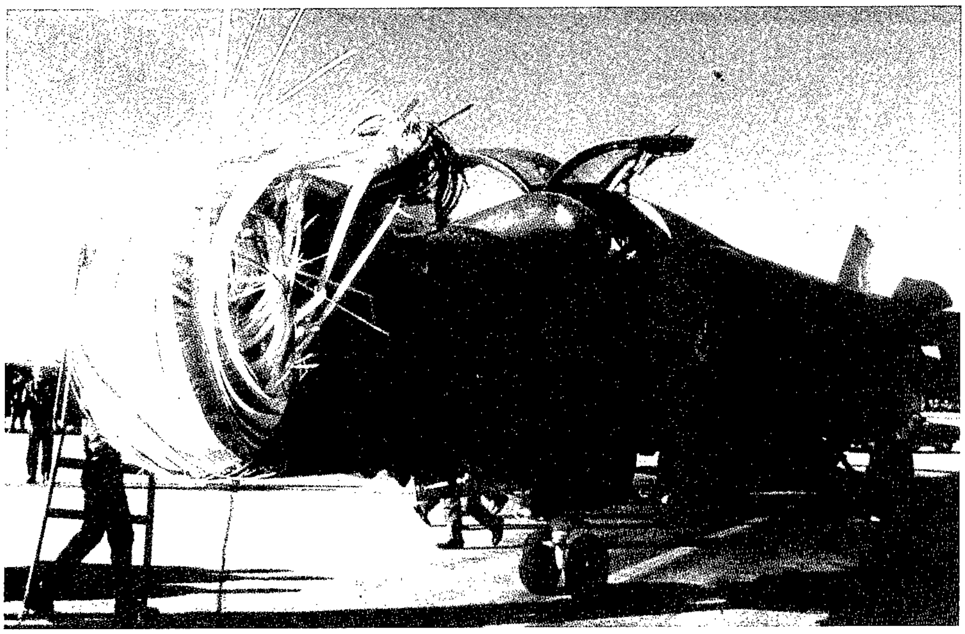




Above: *This flock of starlings, which was photographed over Tel-Aviv, Israel, may cause severe damage to large passenger aircraft (Photo: Jonathan Shaul).*

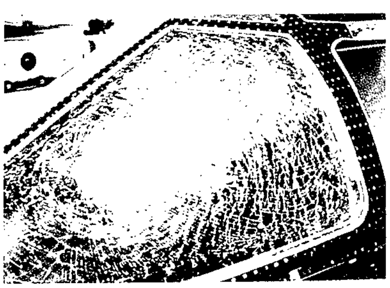
Below: *On 12 November 1975, an American Airlines DC-10 aircraft collided with a flock of seagulls while taking-off from JFK Airport. The aircraft burned completely but all of the 139 passengers managed to escape safely.*





***Above:** An American F-111 bomber whose nose was crushed by a collision with a Red Tailed Hawk. (Photo courtesy: U.S. Air Force)*

***Below:** Strategic bomber B1B hit by birds after a stronger new canopy was developed. The aircraft was saved! (Courtesy: USAF)*



22. On 20 January 1995 there was a fatal accident to a Falcon 20 at Paris Le Bourget due to birds. On take-off, just after rotation, engine 1 ingested Lapwings (Vanellus vanellus, 260g), some of the CF700 fan blades were broken and the fan oversped, departing from the aircraft. Compressor blades entered a fuel rank. The pilot attempted a circuit and return on one engine, but landed heavily near the take-off point and the aircraft caught fire. All 10 occupants died. The accident was at 17.37 hours, at dusk, just after a thunder storm. This was the worst bird strike accident in Europe.

Airliner Fatal Accident

There have been several fatal accidents involving turbo-prop airliners and jet powered executive aircraft, but surprisingly only one fatal accident to a jet airliner. This involved a JT8D engined Ethiopian Airlines Boeing 737 on departure from Bahar Dar airport, in Ethiopia.

Recent Fatal Accidents

i) On 22 September 1995, a JT3D-engined Boeing E3 AWACS, based on the B707 four- engine airliner, was making an early morning departure from Elmdorf USAF base Anchorage, Alaska, USA. Just after the heavily loaded aircraft lifted off, a large flock of Eastern Canada Geese (Branta canadensis, 7kg, 15 lb) were encountered. Birds were ingested in engines 3 and 4, rendering the aircraft unflyable. It crashed on rising ground approximately 40 seconds later killing the 24 crew members. The flock of geese were known to frequent the aerodrome and had probably been alarmed by a C130 which departed shortly before the AWACS.

ii) At Aktion Air Force Base in Greece, another Boeing AWACS was taking off on 14 July 1996. Just beyond the point of rotation a large black bird was seen close to the aircraft moving from left to right. The crew heard a noise on the right-hand side of the aircraft and the aircraft continued to accelerate for another 2-3 seconds at which point the commander initiated a rejected take-off, at a speed beyond that calculated and briefed. The aircraft over-ran the runway into a lake, resulting in the aircraft being severely damaged, the fuselage fractured etc. Of the 14 crew members all escaped, one suffering back injuries. Subsequently, it was found that engine 3 had been struck (bird species unknown) but not damaged. The commander's decision to abandon take-off was influenced by his belief the aircraft had suffered a strike in spite of a bird control programme at Aktion and by his knowledge of the Alaskan accident.

iii) On 15 July 1996, a Belgian Air Force C130 Hercules was approaching Eindhoven, Netherlands. Shortly before landing, a go-around was initiated because of a large number of birds near the end of the runway. Many birds impacted the

left wing area and cockpit and engines 1 and 2 lost power, but the crew feathered engine 3. With engine 4 at full power the aircraft turned left, lost altitude and impacted on the airfield close to the runway. A severe fire broke out but owing to lack of co-ordination of fire control and rescue efforts, and jammed exits, 34 of the 41 on board died because it had been thought that the only occupants were the four crew members. Shortly before the Hercules landed a flock of birds was observed from the control tower, on and around the runway close to the tower.The flock subsequently moved away and were not observed again. Just before the aircraft landed, the bird scarer and Air Traffic Control checked the end of the runway for presence of birds, and none were seen. Subsequent investigation showed that there were between 500 and 600 starlings (Sturnus vulgaris, 80g), together with a few lapwings (Vanellus vanellus, 215g), most of which were presumably in the grass around the runway. The grass had been mowed several days before with the cuttings still lying on the ground. If the birds were in that area, they would have been very difficult to see. It is believed the birds were scared by the aircraft approaching in a tight final turn.

iv) All three of these recent accidents were to military aircraft of a type which are similar to civilian aircraft, and were at airfields with a bird control programme. Birds are unlikely to be influenced by aircraft colour schemes, logos etc, so any of these accidents could easily have involved civil aircraft with much heavier loss of life.

Some Civil Statistics - European Airlines 1980-1985
(The Latest Data Sample Available) (Ref 5)

- When all this data is put together it does look sensible in that the four-engine aircraft, which have a greater frontal area have a higher strike and damage rate than the three-engine and two-engine and that when you come to turbo-prop aircraft these are smaller and take-off at a lower speed, giving the birds more chance to get out of the way, and there are less strikes and damage. Helicopters are slow and noisy with a lot of forward rotor thump and they have an even lower strike and damage rate. This does give confidence in the data.

- Almost 40% of bird strikes are due to gulls, with the Black-headed Gull and the Herring Gull being the most frequently identified. In second place are the Lapwings and this percentage is increasing, followed by swifts, swallows and martins, small summer visitors which don't give much of a problem except to light aircraft and helicopters. Next come birds of prey, mostly outside UK followed by small perching birds such as sparrows and pigeons which are present on many airfields. The corvid family, that is crows, rooks jackdaws, magpies, and ravens, are rarely struck in spite of the fact that they can be seen on many airfields. They are said to be the most intelligent bird family and indeed you can see this when driving on the highway. Most of the crows struck appear to be juveniles.

- The weight of birds identified is of particular importance on the civil airworthiness side. For many years there has been a requirement that catastrophic failure must not result from striking a bird of up to 4 lb in weight. This covers 99% of bird strikes. This 4 lb requirement was excellent because it has meant that, as far as I am aware, no transport aeroplane windshield has ever been penetrated by a bird of any weight, at any speed. Engines were allowed to lose all thrust. However, about 25 years ago a new requirement was implemented that meant that engines had to be able to take a number of 1 lb bir ds depended on the size of the engine and only lose 25% of thrust. The CF6, JT9D, CFM56, Concorde Olympus and RB211 all met this requirement, however, the JT8D is from an earlier era and was not tested with multiple birds. Thus, with an engine that is likely to be in service well into the next century the remedial measures MUST be on the airport. The newest engines meet a requirement for an 8 lb bird and mixed multiple 1 Ω and 2 Ω lb birds.

- The 4 lb requirement is effective, this RB211 swallowed 3 Canada Geese (Branta canadensis, 3.6kg) and was still running, albeit with reduced power.

- Fifty five percent of all bird strikes occur within the first 50 ft with 65% up to 100 ft, 88% of all strikes are below 1000 ft. However, it should be noted that 6% of strikes are above 2500 ft and in fact the highest bird strike known is at 37,000 ft off the West coast of Africa involving a Ruppell's griffon vulture (Gyps ruepellii, 7.5kg).

- As the airspeed increases on take-off birds have increasingly less chance of getting out of the way of an aircraft and up to about 90 to 100 kts there are only a few percent of strikes but above that there is a rapidly increasing risk of a strike taking place.

- The aircraft parts most frequently struck are the windshield, nose and radome area (which account in all for almost 50% of all bird strikes) but the engines account for 17% of which 1.3% are multiple strikes whereby more than one engine is struck. This is the greatest risk. The tail is very rarely struck, only 1% of strikes there but as a result of an accident in America where a Viscount tail plane was removed by a Whistling swan (Cygnus columbianus, 6.9kg), causing the aircraft to crash and kill all 17 people on board. The FAA brought in an arbitrary requirement of 8 lb on the tailplane, in spite of the fact that only 1% of birds are known to be over 4 lb in weight. This requirement, for example, adds about 50 lb of structural weight to even a small aircraft like a Short SD360.

- During this above 5 year period no aircraft were lost, but in the preceding 5 year period 2 aircraft were lost, the Boeing 737 in Belgium and a Learjet in Italy. However, during this period 488 engines were damaged. This, of course, refers to European airlines world-wide and does give some idea of the universal scale of the problem.

Note that windshield damage occured in only 25 cases and these were to the outer layer of the double layer system; either can take the aerodynamic and pressure load. A UK Boeing 727 had the outer layer windshield shattered by an unknown bird at 20,000 ft over St Abbs Head.

General Aviation

- A newspaper headline appeared several years ago when a Piper Navajo struck a White-backed Vulture (Gyps bengalensis, 5.3kg) in one of the Kenya game parks. It came through the windshield, killing the only pilot, the aircraft crashed and burnt, all nine on board died.
- Just 3 weeks later a Cessna 401 in the same Kenya park, struck a bird believed to be a Marabou stork (Leptoptilos crumeniferus, 5.9kg) which removed the wing tip and aileron. It spun down killing all the six on board.
- In Nairobi and at many airports throughout Africa, the Middle East, India, the Far East, Japan, and Northern Australia, the Black kite (Milvus migrans, 780g) is a major problem. It is a scavenging bird of prey which seems impossible to deal with.
- Another hazard is nests, believed to be a jackdaw's, was found in the bottom of the fuselage of a Piper Cherokee amongst control wires. Birds will use anything to build a nest, which could include the remains of stainless steel locking wire picked up from the airfield. Not the sort of thing you want amongst control systems.
- A Leaflet 'Bird Avoidance' is part of the UK General Aviation series and is to help pilots using smaller airfields where there may be no bird control measures.

Bird Populations

Figure 1 shows the steady increase in UK inland wintering gull populations during the last 40 years (Ref 6). This sort of population expansion has occurred in other species, eg Canada Geese (Branta canadensis) Figure 2 and Cormorants (Phalacrocorax sp) (Ref 7,8,9,10). Steps may need to be taken as soon as possible to deal with these rising populations before further accidents occur. A public relations exercise may have to target the environmental protection lobby to persuade them of the need for firm action, as these population explosions are threatening other bird species.

Reporting And Identification

- In order to encourage reporting, publicity posters should be widely distributed.
- These small feather fragments removed from the engine of a jet trainer were successfully used to identify the bird as a Red-tailed hawk (Buteo jamaicencis, 1.1kg).

- All civil data should be sent to ICAO in Montreal for inclusion on the International Birdstrike Information System (IBIS). All countries should automatically receive an annual analysis and the full details on all strikes in the country. Other analyses are available on request.
- All European Military data should be sent to the NATO Database held by Royal Netherlands Air Force.

And Finally

- Severe damage to a JT8D engine as a result of ingesting one Black-headed Gull (Larus ridibundus, 275g), a comparatively small bird.
- ...fan blades had detached, nose cowling had fallen off, the bullet had almost fallen off and some of the debris bounced off the runway and did minor damage to the other engine on the Boeing 737 as well as breaking the outer pane of one of the cockpit side windows.
- ....worst of all, two of the three engine mounting bolts had broken and the engine was only being held by one bolt and the two hydraulic pipers at the rear.
- All concerned must work together to avoid hazardous flocks of birds on airports.
- When things do go wrong it makes the newspaper headlines, a 1-11 over-ran: slightly without any damage after abandoning take-off just at decision speed due to ingesting a gull. There are many airports where the over-run area can be buildings, roads or the sea, and abandoning take-ff means there would almost certainly be loss of life.

Conclusions

i) Recent accidents involving four-engine military aircraft have demonstrated the vulnerability of even this group of aircraft to encounters with flocks of birds.

ii) The threat from small birds which flock densely, e.g. starlings, must not be overlooked, particularly with turboprop aircraft.

iii) Known remedial measures should be backed up by scientific assessment of the effectiveness of new technologies to assist in reducing the frequency of encounters with flocks large enough to effect more than one engine.

iv) If the CAA and FAA are to achieve their declared intention of significantly improving aviation safety during the next decade, all avenues will have to be explored.

v) Although NOT a major cause of accidents to civilian aircraft, bird strikes are nevertheless a serious safety and economic hazard in spite of more resistant modern aircraft and engines.

vi) Even though there are ejector seats, and a much more robust structure, military aircrew are still being killed and injured while the cost of both damage and replacement of destroyed aircraft is increasing.

vii) Birds cannot differentiate between civilian and military aircraft, so whether the collision is with an airliner or a fighter aircraft is a matter of luck, and the general principles are the same.

viii) Where there are increases in both aviation activity and in bird populations, it must be expected that there will be more accidents, therefore appropriate action is essential.

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Aerodrome Bird Hazard Prevention: Case Study At John F. Kennedy International Airport

Richard A. Dolbeer
U.S. Department of Agriculture, National Wildlife Research Center,
6100 Columbus Avenue, Sandusky, Ohio 44870 USA

Abstract

The collision of birds with aircraft is a serious problem at John F. Kennedy International Airport (JFKIA), New York. Gulls (Larus spp.) accounted for 86% of bird strikes (an aircraft striking >1 bird) from 1988-1990, averaging 260 strikes/year. Laughing Gulls (L. atricilla) are present from May-September in association with a protected nesting colony in Jamaica Bay National Wildlife Refuge adjacent to the airport. The colony increased from 15 nests in 1979 to 7,629 nests in 1990. During the 1970s and 1980s, JFKIA implemented various management activities to reduce gull strikes, including maintenance of tall grass, improved sanitation, drainage of standing water, and increased harassment. These programs, although beneficial as part of an integrated bird management program, did not result in reduced numbers of gull strikes. A specific program to reduce gull strikes was undertaken from May-August 1991-1998 in which 2-5 people stationed on airport boundaries shot gulls flying over the airport. In 7,159 person-hours of shooting, 55,452 gulls were killed (2,263-14,866/year), comprised of 50,521 Laughing Gulls and 4,931 other gulls (L. argentatus, L. marinus, L. delawarensis). The number of aircraft striking gulls declined to a mean of 68.4/year in 1991-1995, a 74% reduction compared with the mean of 259.7 strikes/year for 1988-1990. As a result of the shooting program, the overall bird strike rate declined at JFKIA but the proportion of strikes caused by non-gull species increased, from 14% in 1988-1990 to 39% in 1991-1995. To further reduce strikes by gulls and other species and to minimize the need to shoot gulls, JFKIA implemented an experimental falconry program in 1996-1998. Falconry has provided positive publicity for JFKIA and additional personnel on the airport to disperse birds. However, a statistical analysis of strike data did not indicate falconry reduced the strike rate below levels achieved during the shooting program in 1991-1995. In 1996-1998, when shooting and falconry were both active, the mean gull strike rate (57.3/year) was similar to the rate recorded in 1991-1995 (68.4/year). Strikes by non-gull species increased in 1996-1998 (= 85.3/year) compared to 1991-1995 (43.0/year). Non-gulls comprised 60% of all bird strikes, 1996-1998. The number of gulls killed/person-hour of shooting was highest in 1991-1992, the first 2 years of the shooting program, but did not differ ($P > 0.05$) among years from 1993-1998. JFKIA, located in a bird-rich coastal

environment, has developed innovative programs to reduce strikes by various bird species whose dynamic populations present ever-changing challenges. A new component of these integrated programs should be the relocation of the nearby gull nesting colony to a site away from JFKIA.

Key Words: Airport, Bird Strike, Falconry, Gull, Integrated Pest Management, JFK, Shooting

Introduction

The collision of birds with aircraft is a serious problem at John F. Kennedy International Airport (JFKIA), New York. Port Authority of New York and New Jersey (PANYNJ) personnel reported 80-315 aircraft struck by birds/year at JFKIA from 1979-1998 (Dolbeer and Chipman 1999). These strikes have caused millions of dollars in damage to aircraft and represent a significant threat to human safety. From 1988-1990, Laughing Gulls (Larus atricilla) were the species most frequently struck by aircraft at JFKIA, averaging 157 aircraft incidents (52% of all incidents) involving 170 birds (47% of all birds struck)/ year. Other gulls (Herring [L. argentatus], Great Black-backed [L. marinus] and ring-billed [L. delawarensis]), which are present year-round, comprised 34% of the aircraft strikes and another 52 species of birds comprised the remaining 14%. There is a nesting colony of laughing gulls adjacent to JFKIA in Jamaica Bay Wildlife Refuge, a protected area administered by the U.S. National Park Service. This colony increased from 15 nesting pairs in 1979 to 7,629 pairs in 1990. Almost all laughing gull strikes have occurred from May-September with most in June and July during chick rearing (Dolbeer et al. 1989). Nesting Laughing Gulls fly from the colony over the airport to off-airport feeding areas throughout metropolitan New York City (Griffin and Hoopes 1991). Strikes with other gull species occur throughout the year.

As required by U.S. Federal Aviation Administration Regulation 14CFR139, JFKIA has had an active bird management program since the 1970s to discourage birds from feeding, drinking, and loafing on airport grounds. This program has included habitat alteration (tall grass and removal of standing water on airport), the use of vehicle-based bird patrols and runway sweeps, and the deployment of various bird-frightening techniques. However, these measures have done little to prevent laughing gulls and other gull species from flying over the airport to off-airport feeding, nesting and resting sites (Dolbeer et al. 1989, Sillings et al. 1992).

As one approach to solving the problem, U.S. Department of Agriculture (USDA) biologists, under a cooperative agreement with the PANYNJ, initiated an experimental management program at JFKIA in 1991 to reduce strikes by gulls, primarily laughing gulls. From 20 May-8 August 1991, biologists shot gulls attempting to fly over the airport. Hypotheses tested were that shooting would not only directly reduce the number of gulls flying over the runways but also enhance ongoing bird-frightening programs at JFKIA by conditioning gulls to avoid the airport. Because strikes by gulls were significantly reduced at JFKIA

in 1991 (Dolbeer et al 1993), the shooting program was continued during late May-early August in 1992-1998. In 1994, an Environmental Impact Statement (EIS) was finalized that addressed the management of gulls to reduce bird strikes at JFKIA (USDA 1994). The EIS recommended that the shooting program be continued as part of an integrated management program until other actions are taken that would result in relocation of the gull colony.

In 1996-1998, the PANYNJ implemented experimental falconry programs to complement the shooting program. The PANYNJ contracted with falconers (different contractor each year) to fly trained falcons and hawks, in addition to using traditional bird-scaring techniques (e.g., pyrotechnics), from June-October 1996, July-November 1997, and May-November 1998 (Table 1). The falconry contractor active in 1998 will continue through 2000. Having shooting and falconry programs conducted during a 3-year period, combined with a long-term database on bird strikes (Burger 1985), provided a unique opportunity to examine the effectiveness of these 2 programs (1996-1998) compared to baseline years when only shotgun shooting was done (1991-1995) and when neither program was active (1988-1990).

Methods

Shooting

Shooting was with 12-gauge shotguns using primarily #4 steel shot (250 rounds of #2 steel shot were used in 1998) on 31-62 days annually from May-August 1991-1998 (Table 1). Two to five shooters were stationed along the southern airport boundaries where gulls often crossed the airport. Shooting typically was conducted from 0530-1300 or from 1300-2030. Shooters stood or sat in the open and wore blaze-orange vests. Shooting was directed away from the airport at flying gulls that came within range (about 40 m).

All shooters operated under federal and New York State permits issued to the USDA or PANYNJ. In 7,160 person-hours of shooting in 1991-1998, 55,452 gulls were killed, comprised of 50,521 laughing, 3,632 herring, 722 great black-backed, and 577 ring-billed gulls (Table 1). The Laughing Gull colony declined from 7,629 nests in 1990 to 5,448 nests in 1998. Dolbeer et al. (1993, 1997), Dolbeer and Bucknall (1994) and Dolbeer and Chipman (1999) provide additional details about the shooting program and nesting colony.

Falconry

Falconers generally flew their birds (primarily peregrine falcons [Falco peregrinus], peregrine-gyrfalcon [F. rusticolus] Hybrid, Saker falcons (Falco cherrug), and Harris' hawks [Parabuteo unicinctus]) daily on the airport. Typically, the falconers used "lure flights" in which the falcon did not attack and kill target birds but simulated hunting by chasing a lure

swung from a leash by the falconer. In addition, the falconers used pyrotechnics, amplified distress calls and occasional shotgun shooting with live ammunition to disperse birds. Watermann (1997), T. C. Management (1998) and Falcon Environmental Services (1998) provide additional details about the 1996-1998 falconry programs.

Evaluation of shooting and falconry

Bird strikes have been consistently recorded daily at JFKIA since the mid 1970s. Bird strikes are classified as "pilot-reported" when a person (usually a pilot) reports a strike and 'unreported" when JFKIA bird-patrol personnel find bird remains within 200 feet of the centerline of an active runway and no other cause of death is suspected (Burger 1985).

To evaluate the shooting and falconry programs, I made comparisons of strike rates (number of strikes/year) for gull species and all other bird species (hereafter referred to as "non-gull species") among years using chi-square statistics for proportional data (Fleiss 1973:14-22). First, I compared strike rates for 1988-1990 (baseline years in which there was no shooting or falconry) with strike rates for 1991-1995 (shooting but no falconry). Second, I compared strike rates for 1991-1995 (shooting but no falconry) with strike rates for 1996-1998 (shooting and falconry). In making comparisons among years, I first used all strikes (unreported and pilot-reported combined) and then repeated the analysis using only pilot-reported strikes. In all analyses, I used number of strikes instead of number of strikes/10,000 aircraft movements as the response variable because aircraft movements at JFKIA (355,000 in 1996) have increased by only about 3% per year, 1988-1997 (USDA 1994; Lampl 1998).

To determine if the falconry program reduced the number of gulls shot in 1996-1998, when shooting and falconry were conducted simultaneously, I used 1-way analysis of variance to compare the mean number of gulls shot/person-hour of shooting, 1991-1998, and tukey tests to determine which annual means were different ($P < 0.05$) (Statistix 1994).

Results

Strike Rates: 1988-1990 (No Shooting, No Falconry) vs. 1991-1995 (Shooting, No Falconry)
Strikes with gull species: In 1991-1995, when shooting but no falconry was done, there was a mean reduction of 74% ($X2 = 111.69$, 1 df, $P < 0.01$) in all strikes (unreported and pilot-reported) with gulls (= 68.4 strikes/year) compared to the annual mean for the baseline years, 1988-1990 (= 259.7 strikes/year, Fig. 1). When only pilot-reported strikes were considered, there was also a significant ($X2 = 6.28$, 1 df, $P = 0.02$) mean reduction (64%) in strikes with gulls in 1991-1995 (= 7.6 strikes/year) compared to 1988-1990 (21.0 strikes/year, Fig. 2).

Strikes with non-gull species: For all strikes (unreported and pilot-reported), there was

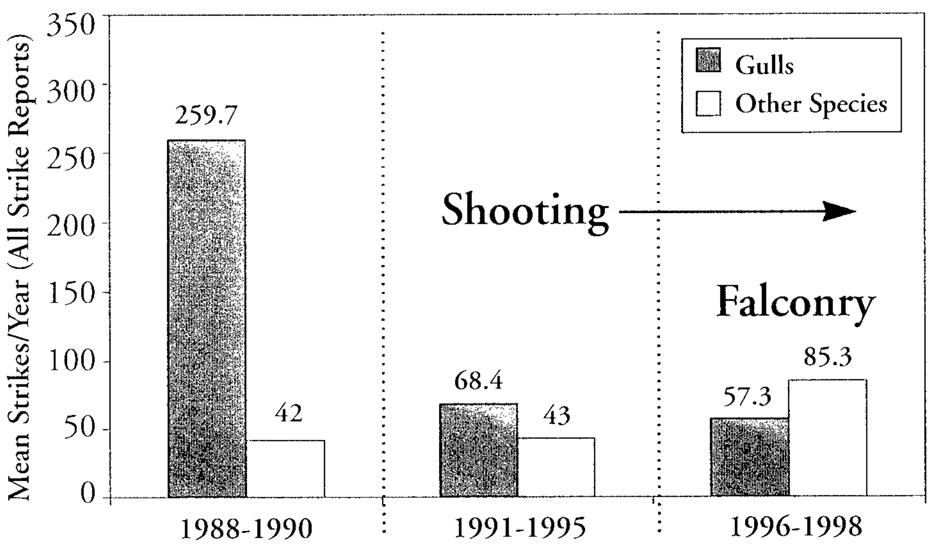


Fig. 1 Mean number of bird strikes/year (pilot reported and unreported) involving gull species and other bird (non-gull) species, JFK International Airport, New York, 1988-1990 (baseline years), 1991-1995 (shooting) and 1996-1998 (shooting and falconry)

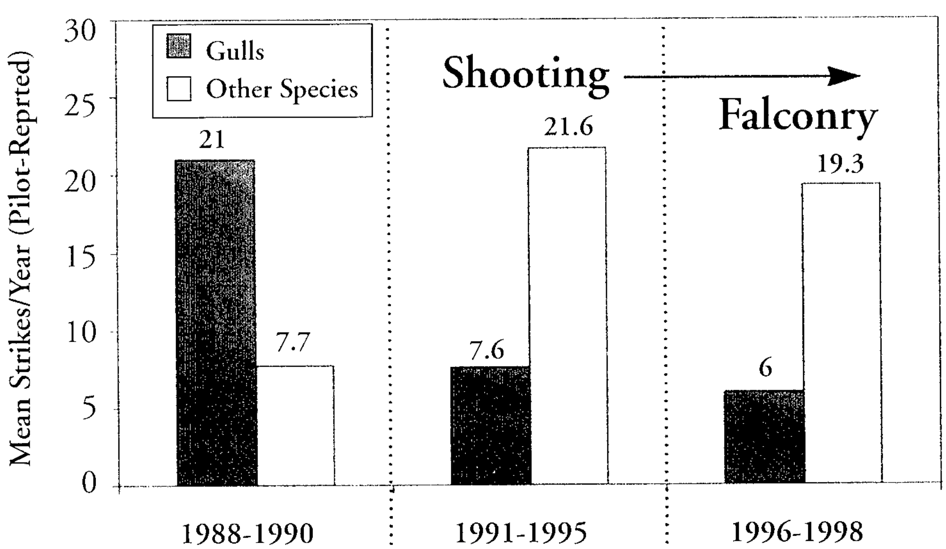
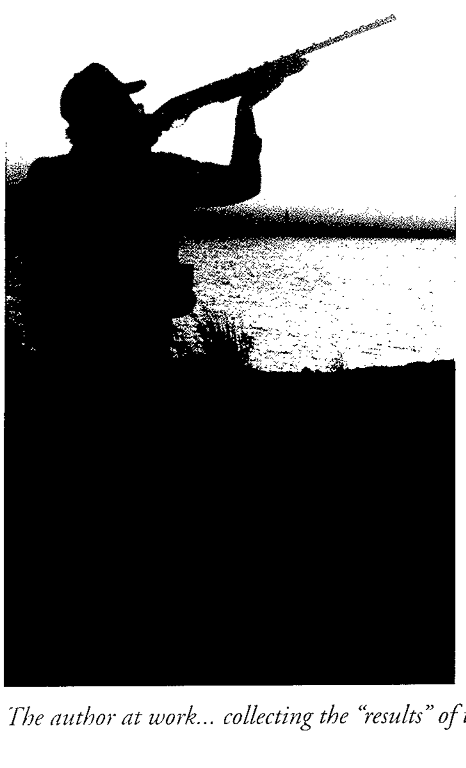
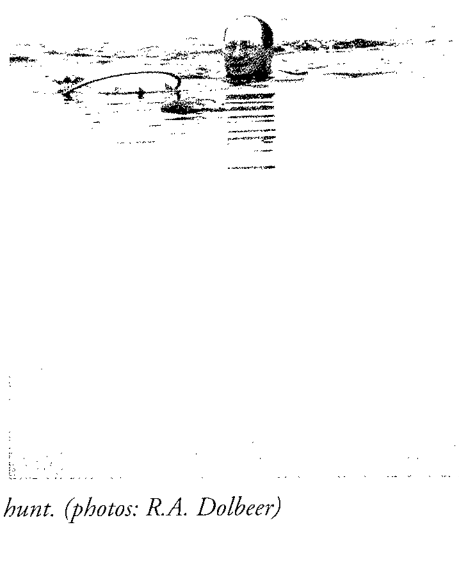


Fig. 2 Mean number of pilot-reported bird strikes/year involving gull species and other bird (non-gull) species, JFK International Airport, New York, 1988-1990 (baseline years), 1991-1995 (shooting) and 1996-1998 (shooting and falconry)





The author at work... collecting the "results" of the hunt. (photos: R.A. Dolbeer)

no difference (X2 = 0.01, 1 df, P = 0.90) in the mean annual strike rate for non-gull species between 1991-1995 (= 43.0 strikes/year) and the baseline years, 1988-1990 (= 42.0 strikes/year, Fig. 1). However, when only pilot-reported strikes were considered, there was a 2.8-fold increase (X2 = 6.67, 1 df, P = 0.01) in strikes for non-gull species from 7.7/year in 1988-1990 to 21.7/year in 1991-1995 (Fig. 2).

Strike Rates: 1991-1995 (Shooting, No Falconry) vs. 1996-1998 (Shooting, Falconry)

Strikes with gull species: For all strikes (unreported and pilot-reported), there was no difference (X2 = 0.98, 1 df, P = 0.33) in the mean annual strike rate between 1991-1995 (= 68.4 gull strikes/year) and 1996-1998 (= 57.3/year, Fig. 1). When only pilot-reported strikes were considered, there also was no difference (X2 = 0.19, 1 df, P = 0.72) in the mean annual strike rate between 1991-1995 (= 7.6 gull strikes/year) and 1996-1998 (= 6.0/year, Fig. 2).

Strikes with non-gull species: For all strikes (unreported and pilot-reported), there was a 2-fold increase (X2 = 13.94, 1 df, P < 0.01) in the mean annual strike rate from 43.0/year in 1991-1995 to 85.3/year in 1996-1998 (Fig. 1). However, when only pilot-reported strikes were considered, there was no difference (X2 = 0.14, 1 df, P = 0.70) in the mean annual strike rate between 1991-1995 (= 21.7 strikes/year) and 1996-1998 (= 19.3/year, Fig. 2).

Number of Gulls Killed per Person-hour of Shooting: 1991-1998

The number of gulls killed/person-hour during the shooting program differed (P < 0.01) among years, 1991-1998 (Table 1). The kill/person-hour was significantly (P < 0.05) higher in 1991, the first year of the program, than in any of the subsequent 7 years. The numbers killed/person-hour in 1996-1998, when falconry and shooting were done simultaneously, were the lowest for the 8 years but were not different (P > 0.05) than means in 1993-1995.

Changes in Species Composition of Birds Struck By Aircraft, 1988-1998

In 1988-1990, strikes with gulls (= 259.7/year) represented 86% of all strikes recorded (= 301.7/year, Fig. 1). During the first 5 years of the shooting program (1991-1995), the percent of strikes involving gulls declined to 61%. In 1996-1998, gulls (= 57.3 strikes/year) comprised only 40% of the species involved in strikes (= 142.6 strikes/year).

Discussion

Shooting gulls at JFKIA clearly reduced the number of strikes with gulls, based on a comparison of strikes in 1988-1990 (baseline years) and 1991-1998 (shooting). No nontarget gulls or other wildlife were affected because shooting with nontoxic shot was directed only at gulls attempting to fly over the airport. However, this shooting program resulted in the killing of 55,452 gulls. In an effort to develop alternative, nonlethal

methods to reduce strikes, the PANYNJ added falconry to their integrated bird management program at JFKIA in 1996-1998.

The statistical analysis of strike data (both all strikes and pilot-reported strikes), however, did not support the hypothesis that the falconry programs in 1996-1998 reduced gull strikes at JFKIA below baseline levels achieved by the shooting program in the 5 years immediately prior to falconry. There were slightly fewer gull strikes in 1996-1998 compared to 1991-1995, but the reductions were not statistically significant and the strike numbers were within the range of values for 1991-1995. In addition, the number of gulls killed/person-hour of shooting was not statistically different among years in 1993-1998.

As noted by Blokpoel (1976), falconry on airports has attracted public interest because it uses a medieval sport to protect modern jet aircraft. Falconry, as practiced at JFKIA, is also attractive to the general public in that it is a biological control procedure in which birds are usually only dispersed and not killed. JFKIA has, indeed, received considerable positive media coverage in 1996-1998 regarding the falconry program as an environmentally friendly means of reducing bird strikes (L. Rider, PANYNJ, Personal Communication). Another benefit has been that the falconers, during their daily routines, provide additional personnel on the airfield to harass birds using a variety of methods in addition to falconry as a supplement to the regular bird patrol staff at JFKIA. JFKIA has not sacrificed other components of their bird management program to employ the falconers (L. Rider, PANYNJ, Personal Communication).

In 1991, the PANYNJ naturally focused management efforts on gull species because gulls comprised 86% of all recorded strikes, 1988-1990. The shooting program at JFKIA in 1991-1998 was designed to deal with this specific problem of gulls from a protected wildlife refuge adjacent to JFKIA flying over the airport to dispersed feeding sites beyond the airport. As a result of this shooting program directed specifically at gulls, strikes with gulls were reduced by over 70%. By 1996-1998, gull species comprised only about 40% of the strikes. However, strikes by non-gull species increased during the 1990s, both in absolute numbers and as a percent of the total strike rate, from 1988-1990 levels. There was no evidence from the analysis of strike data (all strikes and pilot-reported strikes) that the combined gull-shooting and falconry programs in 1996-1998 reduced the number of strikes by these non-gull species from levels recorded in 1991-1995.
Aside from the specialized shooting program directed specifically at gulls, the PANYNJ should continue in their commitment to develop an innovative, integrated bird management program, including habitat management and the use of various bird-frightening techniques, to prevent gulls and other bird species from using the airport (USDA 1994). Falconry, which provides positive publicity and other unique attributes, can have a role in this integrated bird management program at JFKIA. However, additional years of data are needed to provide a more complete assessment of the exact role that falconry can play in reducing strikes. Negotiations with the U.S. National Park Service should continue to develop a program to relocate the gull nesting colony adjacent to JFKIA to a site away from the airport.

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The Role and Value of Awareness Programs in Reducing Bird Hazards to Aircraft

Bruce Mackinnon

Transport Canada, Safety and Security, Aerodrome Safety Branch, 330 Sparks St., Place de Ville, Tower C, Ottawa, Ontario, K1A ON8, Canada

Abstract

In our continued effort to manage the risk associated with collisions between wildlife and aircraft, we frequently rely on traditional processes, and forget that significant progress can often be made with simple education and awareness programs. Three ongoing issues in Canada serve to highlight this point.

First, despite the fact that the aviation industry is heavily regulated, few countries, including Canada, have comprehensive regulations and standards which effectively address the risk associated with bird strikes to aircraft. Furthermore, in Canada, as in other parts of the world, decision makers often approve or promote land use activities near airports that seem to be incompatible with the goal of reducing bird hazards to aircraft. Finally, the privatization of Canada's airport system has led to a greater concern among airport executives about the risk of corporate and personal liability when aircraft are involved in wildlife-related incidents at their facilities.

Regulatory deficiencies are currently being addressed by Transport Canada through an initiative that should result in regulations and standards being included in the Canadian Aviation regulations (CARS) within the next year. Also, an increasing number of recent decisions regarding land use activities near airports that have the potential to attract birds have been made with due consideration for the maintenance of aviation safety, and improvements are continually being made to airport wildlife control programs at Canada's major airports as airport executives strive to minimize their liability exposure. In all three of these issues, it is clear that enhanced awareness among decision makers has caused them to consider bird hazards more thoroughly in their decision making process.

Introduction

In our continued effort to manage the risk associated with collisions between wildlife and aircraft, we frequently rely on traditional processes, and forget that significant progress can often be made with simple education and awareness programs. Three ongoing issues in Canada serve to highlight this point.

First of all, Canada, as in many nations, has a limited regulatory structure respecting wildlife control at airports. This situation has resulted in a somewhat ad hoc and inconsistent

approach to implementing wildlife control programs across the system.

Second, decision makers in Canada, as in other parts of the world, have occasionally approved or promoted land use activities on and near airports that at face value appear to be incompatible with the goal of reducing bird hazards to aircraft. Recent examples of such controversial activities are as follows:

- In order to obtain Federal Government approval to construct a parallel runway at Vancouver International Airport, an environmental assessment process was undertaken. Several recommendations provided by the environmental assessment panel dealt with the public's concern that new airport development projects would have an impact on bird habitat and populations on Sea Island, where the airport is located. In order to address these concerns, Transport Canada agreed to create a conservation area immediately north of the new runway. Preliminary plans for the conservation area included an extensive avifauna enhancement program, involving facilities such as nesting boxes, perch poles, and other artificial habitat features designed to attract raptors.
- The airport in St. John's, Newfoundland has operated for many years within 5 km of the Robin Hood Bay waste disposal facility. This site has operated without the benefit of modern waste management technology, and has always been an attractive feeding location for some Herring Gulls, Great Black-backed Gulls, and Glaucous Gulls. In spite of this attraction for birds, a thriving fishing industry combined with abundant capelin stocks has traditionally provided sufficient food resources for the majority of gulls on the east coast of Newfoundland. This active fishing industry has allowed for a relatively comfortable coexistence between the airport and the waste disposal facility. However, a significant decline in capelin and cod stocks on the east coast of Canada in the past few years has forced the Canadian Government to close major portions of the Atlantic fishery, and gulls have been deprived of their customary food source. These factors, combined with the existence of an abandoned runway at the airport, have resulted in the creation of a significant bird strike hazard to aircraft. Many thousands of gulls now feed at the waste disposal facility, intersect approach-departure paths on their flights to and from roosting sites, and rest on the abandoned runway, thereby creating an unpredictable hazard to operational runways whenever they move.
- The municipality of Collingwood and the Province of Ontario have recently identified a requirement for a new waste disposal facility. The chosen site lies within 3 km of the local airport, which for the most part handles general aviation traffic. On occasion, however, small corporate jets such as Cessna Citations operate at the facility. A bird hazard study by one of Canada's leading consultants concluded that the development of a waste disposal facility on the chosen site could produce a serious bird hazard problem at the Collingwood Airport. In spite of the consultant's report and a lobbying effort by local airport users, the province and municipality

have remained committed to develop the landfill site.

Decisions related to land use planning similar to those described above have resulted in circumstances contributing to a number of serious bird strike incidents, examples of which are as follows:

- On June 17, 1993, a Canadian Airlines International B737 departed Calgary International Airport on Runway 28, bound for Vancouver. Immediately after rotation the aircraft struck a large flock of gulls, causing severe damage to both engines and leading edge slats. The flight crew reduced power on the left engine after it developed compressor stalls and began to torch and surge. Power was also reduced on the right engine because of high vibration levels. The Captain declared an emergency and returned to the airport for an uneventful landing. Damage to the aircraft amounted to $4.0 million. Over 60 dead gulls were found on the runway after the incident, and it was likely that these birds had been resting at the airport enroute to a local waste disposal facility.
- On June 18, 1994 a Cessna 441 Conquest with one pilot and six passengers onboard began a takeoff from Fort Frances, Ontario. After approximately 1600 feet of ground run, the left engine ingested a gull causing the engine to lose power. The aircraft lost control during takeoff and crashed. The pilot was unhurt, and the passengers suffered minor injuries. The Transportation Safety Board concluded that the gulls which were struck by the aircraft were likely resting at the airport prior to feeding at a garbage dump located less than two km away.
- On July 26, 1998 an Air Canada B767 departed St. John's, Newfoundland, and reported a possible bird strike. Upon reaching 9000' AGL the crew felt a significant vibration in the starboard engine. The aircraft returned and landed safely at St. John's. A maintenance investigation found that seven fan blades in the starboard engine had been damaged. The damaged blades and their reciprocals were replaced and the aircraft was returned to service.

These incidents and the potential for others like them pose a financial threat as well as a physical threat to the safety of people involved directly or indirectly with aviation, which leads us to the third issue regarding wildlife control at Canadian airports. The potential for severe financial repercussions to airport operators has risen in recent years due to the increasing possibility of legal action resulting after a wildlife incident. The threat of litigation looms heavily whenever an aviation incident occurs and with the continuing privatization of Canada's airports, operators are often left without the protective umbrella once provided by the federal government. This has led to greater concern among airport executives about the risk of corporate and personal liability.

The Awareness Program

An examination of bird strike incidents and land use issues caused Transport Canada managers to conclude that a major contributing factor to our problem was the general lack of awareness within the aviation community and among land use planners on matters related to bird hazards. Although this conclusion was by no means ground-breaking, it was apparent that an aggressive awareness campaign within Canada might go a long way towards minimizing some problems. We decided that we would initiate a comprehensive awareness program in the hope that decision makers would consider bird hazards more carefully when planning land use activities near airports. We also felt that increased awareness might encourage airport operators to improve the quality of their wildlife control programs, lead to more accurate reporting of bird strikes by the aviation community, and provide flight crews with better information for their decision making process.

With respect to the Parallel Runway Project at Vancouver International Airport, once decision makers were made fully aware of the risks associated with the enhancement project in the Sea Island Conservation Area, a lengthy and costly process was initiated by Transport Canada in order to assess the risk to aircraft operations resulting from the program. As a result, the program has been considerably scaled down, and a comprehensive risk management process has been developed in order to identify and mitigate any risk that may develop in the future from the management of the conservation area.

Initially, in the case of the Robin Hood Bay Landfill site in St. John's, Newfoundland, the significant cost of implementing modern waste management techniques delayed progress in resolving the risk to aviation that the landfill creates. However, once the mayor and his council were made aware of the significant hazard to aircraft that was created by their landfill, the costs of providing settlement and compensation after an aviation accident, and their personal liability exposure, considerable resources were made available to improve the management of the landfill.

Little progress was made in the resolution of the landfill development proposal in Collingwood, Ontario, until municipal officials were made aware of the fact that the landfill proposal threatened the community's chances of becoming a major ski resort destination. Wealthy skiers often fly to a destination resort in their business jets, and the hazards created by a landfill in the approach/departure path of the airport's single runway would likely cause many wealthy skiers to choose another holiday resort, thereby depriving the community of its resort and clientele. Although the issue is not yet resolved, it is unlikely that the landfill will be constructed in the proposed location.

Often, it is the third issue involving the fear of personal and corporate liability among decision makers that can most effectively be influenced by proactive awareness programs. Recent court settlements and judgments in Canada as well as other parts of the world provide justification for this concern. It is our opinion that these heightened levels of awareness have resulted in more effective and higher quality wildlife control programs at Canada's major airports in recent years, resulting in programs that currently meet

the standards that Transport Canada is developing.

Although Transport Canada remains committed to developing regulations and standards respecting wildlife control at airports, it can be argued that other processes may have equal value. The privatization of Canada's airport system has shifted the burden of liability from the Federal Government to the private sector. The fear of liability exposure has influenced most of Canada's major airport authorities to incrementally improve their wildlife control programs to ensure that they have achieved due diligence. Furthermore, a good argument can be made that a change in culture within the aviation industry can be achieved through aggressive and proactive education and awareness programs, and this change in culture will cause decision makers to want to prevent wildlife incidents and accidents.

1. POSTERS

We began our program with the decision that we needed a bird strike 'corporate logo.' We contracted a local artist and graphic designer to produce a set of posters that could be used as the logo on a number of products. The goal of the poster campaign was to have one poster describe the problem, and the other a range of solutions. A third poster highlighted the threat to aviation safety posed by rapidly increasing populations of some waterfowl species. Three additional posters were also developed which are designed to assist airport wildlife control officers in identifying bird species at their airport. We wanted these posters to be sufficiently attractive so that managers and others within the aviation community would willingly display them in their offices and other facilities. All of these posters were printed in French and English, and have been widely distributed.

2. VIDEOS

We decided to produce four VHS videos that would provide a range of information on bird hazards to aircraft. **The first video**, *Sharing the Skies* is a general awareness video that provides an overview of the bird hazard problem, and describes a number of mitigating measures that can be taken by airport operators to minimize the problem, including habitat modifications and active bird dispersal techniques.

The second video, *There's Something Out There* is a thirty minute training aid that was produced to compliment the two day airport Wildlife Control Training Seminar that we have also developed. This video provides specific instructions to those involved in the management of wildlife at airports, and describes many of the techniques currently being used in Canada, including habitat modification, falconry and pyrotechnics. It is also intended for use at small airports that may not be able to afford to send personnel to a formal wildlife control course.

The third video, *Not In My Backyard* is an awareness video produced specifically for airport operators and municipal officials who may be involved in developing waste disposal facilities. The video is intended to provide information about the dynamics that can

be created as gulls move among feeding, resting, and roosting sites. It uses the St. John's Airport situation as a case study to show how a poorly located waste disposal facility can result in significant flight safety problems.

The fourth video. *Crossed Paths* provides detailed statistics regarding the number of strikes and their effects. This video also discusses where and why strikes occur as well as giving details about bird species and aircraft types most frequently involved in wildlife incidents. It also covers some of the basic methods of aerodrome wildlife control, and was produced as an update to *Sharing the Skies.*

3. Wildlife Control Procedures Manual

The first edition of Transport Canada's Wildlife Control Procedures Manual had been in use for several years, and although it was a useful document, we felt that it could be improved with an update. We solicited comments from those who had been using the manual, and hired a university student to incorporate the comments that we received, and include new features such as bird weights and photographs. We reorganized the manual to make it easier to find information items, and also to allow it to become the basis for the Wildlife Control Training Seminar that we were developing. The updated manual was printed and distributed to most Canadian airports, and throughout the aviation community.

4. Bird Strike Summary Reports

Transport Canada has been collecting and analyzing bird strike data for many years. We collect data from a number of sources, but primarily from pilots, airlines, airports, and the Department of National Defence. We produce an annual summary of bird strikes at Canadian airports, and in spite of commonly known data deficiencies, the summary reports are very useful in assessing problems at a specific airport from year to year, and also a in tracking trends such as species struck, or damage rates to engines.

5. Aeronautical Information Publication (AIP) Bird Hazard Section

The Aeronautical Information Publication, or AIP, is a loose-leaf book used by all pilots in Canada as an information source for aviation matters. The section on bird hazards had not been updated in a number of years, and provided outdated information on the reporting of bird strikes. We updated the section, and included new bird migration maps and the new Bird/Wildlife Strike Report Form. We have recently amended the chapter again to include information on electronic reporting of bird strikes, as well as the use of our toll-free reporting line.

6. Bird Migration Maps

Migration maps had originally been prepared by Transport Canada and Environment Canada 25 years ago, to be included with the bird hazard section of the AIP. The maps

were intended to provide pilots with information as to when and where to expect the largest concentrations of migrating waterfowl. We worked with Environment Canada biologists to update these maps, and discovered some interesting information. In the 25 years since the maps were first prepared, populations of Ross' Geese, White Fronted Geese, Greater Snow Geese, Large Race Canada Geese, Blue, and Lesser Snow Geese have all shown dramatic increases in numbers. The other significant change noted was the remarkable growth in populations of resident Canada Geese in Vancouver and the Great Lakes areas.

7. Pilot Brochures

During interviews and discussions with pilots, we determined that very little information on bird hazards to aircraft had been provided to them. We found that few pilots had read the bird hazard section of the AIP, and much of what they knew of bird behaviour was incorrect. We felt that a colourful, attractive brochure might capture some interest within the pilot community, and make them more aware of birds and the associated hazards. We produced a small brochure, based on the CAA bird avoidance pamphlet, and distributed 55,000 of them to all licensed pilots in Canada along with the AIP amendment and migration maps.

8. ATC Brochures

This brochure was designed with the intent of educating ATC personnel about the hazards posed to aircraft by birds and other wildlife. The brochure gives some basic bird strike facts, and highlights the important role that ATC can play in preventing wildlife incidents.

9. Bird/Wildlife Strike Report Form

The collection of bird strike data is problematic in Canada, as in most other parts of the world. Adding to our problem was the fact that there were at least four different reporting forms in circulation within the aviation community, and completed forms were being sent to a number of different addresses - some of which were no longer in existence. There were also problems with insufficient numbers and availability of forms. We estimated that we were receiving reports on approximately 30% of actual occurrences, and we hoped that a new, consolidated form might enhance our reporting rate. We designed and developed a new Bird/Wildlife Strike Report Form through consultation with stakeholders such as Bird Strike Committee Canada members, and after a two year process, we printed 30,000 forms with stamped, self addressed envelopes attached. The forms were designed to be easily used, with shaded areas for the essential information that we wanted pilots to provide. We have distributed these forms to most locations within the Canadian aviation community, and have recently printed and distributed additional copies.

10. Aerodrome Safety Information Circulars

Transport Canada issues safety circulars to its many stakeholders. The Aerodrome Safety Branch issues Aerodrome Safety Information and Advisory Circulars to approximately 1600 aerodromes in Canada. We have issued five circulars in the past 3 years that relate to wildlife control issues. The topics range from the procedures to follow for feather identification, to the distribution of a report that was prepared for us by LGL Ltd. on the efficacy of the various products and techniques that are used for the control of wildlife at airports.

11. Toll Free Reporting Number

To further encourage the reporting of wildlife incidents we at Transport Canada have established a toll free hotline (1-888-282-BIRD) through which bird strikes and other wildlife incidents can be reported directly to us.

12. Bookmark

A bookmark was also created with a message encouraging those in the aviation community to report all bird strikes to Transport Canada. Included on the bookmark are the mailing address for the Aerodrome Safety Branch of Transport Canada in Ottawa, the internet address of Transport Canada's wildlife control website, and the number of our toll free bird strike reporting hotline. The bookmark has been distributed to all licensed pilots in Canada.

13. Wildlife Bulletins

Transport Canada has produced a number of Airport Wildlife Management Bulletins over the years, which are intended to provide timely information to the Canadian aviation community on events related to wildlife management and aviation safety. We have distributed 23 bulletins to date. The package of bulletins that we currently distribute discusses topics such as: land use adjacent to airports, the growing risk from large birds, new technologies available for wildlife control, wildlife control beyond airport boundaries, deer hazards, legal and financial necessities in wildlife control, and the human element in wildlife control. We are currently completing a bulletin that deals with risk assessment and management planning.

14. Aviation Safety Letter And Aviation Safety Vortex

Several articles about bird strikes and wildlife incidents have been written and included in issues of Transport Canada's Aviation Safety Letter which is distributed to all licensed pilots in Canada. We have also included articles in issues of Transport Canada's Aviation Safety Vortex newsletter which is distributed to all licensed helicopter pilots in Canada.

15. Wildlife Control Training Seminar

Traditionally, Transport Canada has provided training to wildlife control officers by organizing one five day training course each year at varying locations. These courses were available to a limited number of students per year, and due to budget constraints, the people who carried out actual wildlife control activities were not always the people selected to attend the course. We reviewed the make-up of the five day course, and determined that it could be presented as a two day Wildlife Control Training Seminar which has been packaged so that it can be delivered on short notice to specific airports. This package enables a three person instruction team to travel to a site, and deliver a seminar to the staff tailored to their specific needs at a much lower cost than before, when the instructors and many of the students paid travel costs. We are now easily able to deliver four seminars to 100 students per year, rather than 25 students as was the case with the former training program.

16. Bird Strike Committee Canada

Transport Canada co-chairs two Bird Strike Committee Canada meetings each year. The first meeting, held in the spring, is a joint meeting between members of both Bird Strike Committee Canada and Bird Strike Committee USA. The second meeting, held in the fall, is specific to Canadian BSCC participants and is held at selected airports in Canada so that we can review various issues as a committee, and provide advice and assistance to the airport operator. The committee's role is to provide a forum for the exchange of information on wildlife-aviation issues. The waste disposal industry has been solicited for input and has become more active with the committee over time. Lines of communication have also been developed between Bird Strike Committee Canada and the Ontario Ministry of the Environment in order to deal with land use development proposals near airports that have the potential to attract birds. We are hoping to reduce the conflict that arises during the planning process for waste disposal facilities when industry people discover that bird hazards are an issue. Following each meeting, we distribute the proceedings to committee members and participants which enables us to append general information items that we receive at Transport Canada between meetings. These appendices help to maintain a high level of awareness among those involved in the committee.

17. Website

A wildlife control website (*http://www.tc.gc.ca/aviation/wildlife.htm*) was also created in order to provide access to information regarding wildlife control and wildlife incidents. The website allows access to documents such as the minutes of the Bird Strike Committee Canada meetings, Bird Strike Summary Reports, Airport Wildlife Management Bulletins, and the Wildlife Control Procedures Manual. Bird strikes and other wildlife incidents can also be reported to Transport Canada through the website.

Results Of The Awareness Program

We would like to be able to report remarkable and dramatic results in the management of bird strike issues following the enhancement of our awareness program, but in fact, what we have seen so far is somewhat more evolutionary.

There has been a noticeable increase in the interest shown by the Canadian aviation community to bird strike issues, judging from the number of requests for information and awareness products that we receive, and we have kept one co-op student very busy responding to these requests. We have noticed that our posters decorate the walls of many airports and Transport Canada offices, and products such as Wildlife Bulletins and Wildlife Control Procedures Manuals have been sent to all parts of the world. Airport operators have responded positively to the wildlife control training seminars, and we will continue to deliver these upon demand. We have been able to train up to four times as many students per year since the initiation of the new training program.

Flying clubs, private pilots, and both large and small airlines have used the Bird/Wildlife Strike Report Form since its introduction. Canadian Airlines placed 1,000 forms in the flight decks of their aircraft, and Air Canada distributed several thousand to its operations centres. Since the inception of the awareness program we have been receiving better information and more of it from commercial pilots. The number of reports received in 1998 is up by 9.5% from the number received in 1997 and up by 27.5% from the number received in 1994. A greater increase was expected in the reporting rate, but we assume that increased interest shown by Canadian airport operators has caused some of them to manage wildlife problems more effectively, and thereby lower their strike rate. Also less flying by Canada's Department of National Defence has resulted in fewer reported strikes. It is also worth noting that the number of reported significant strikes in 1998 increased by 15% compared to the number of reported significant strikes in 1997.

We feel that the awareness program has had a significant positive effect on the management of airport wildlife control programs. A number of airport operators have become involved and remain involved with Bird Strike Committee Canada. A considerable number of them have initiated ecological surveys for the purpose of developing a systems approach to the management of wildlife at their airports. A number of consultants studies are currently ongoing in order to develop airport wildlife management plans, and in general, the larger airports have assessed and improved on the methods and techniques they formerly used to control wildlife. There also appears to be a willingness to take a stronger stand when dealing with public concerns about wildlife preservation near airports.

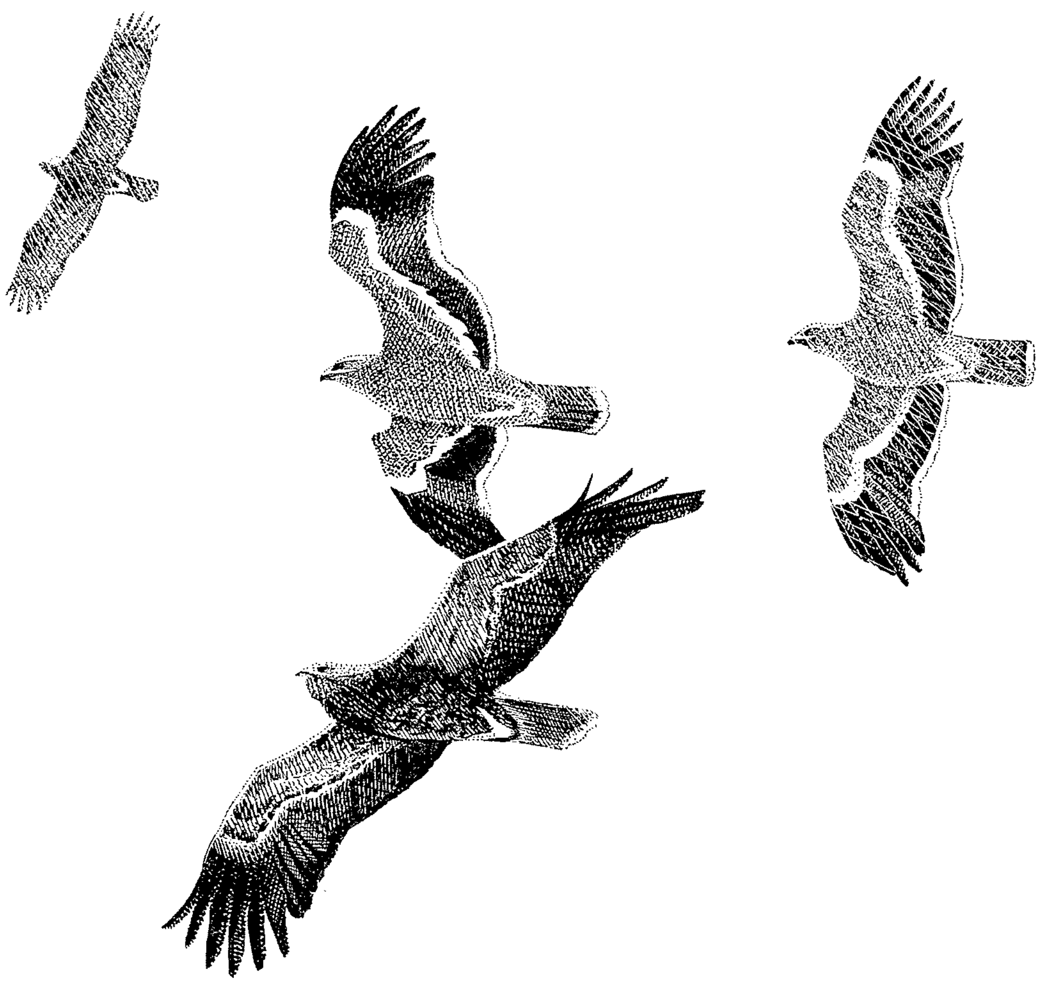
One of the most encouraging developments since the beginning of the awareness program is the interest that has been shown by the waste disposal industry towards resolving bird hazard issues. Company representatives from two large waste system companies, Laidlaw and BFI, have willingly participated in Bird Strike Committee Canada meetings, with

a view towards learning more about the impact their operations may have on aircraft safety. Another important development occurred in 1998 with the proposed re-opening of the Quinte Landfill site. The proposed landfill lies less than two kilometres from the main runway at Canadian Forces Base Trenton directly beneath the approach/departure path. The Department of National Defence was concerned about the potential danger from bird strikes that could result from re-opening the landfill. The Environmental Assessment Board found that there would have been a serious hazard from re-opening the landfill and concluded that, "...any plan to reopen the landfill site should ensure a zero tolerance of increased bird activity in order to protect public safety." (Environmental Assessment Board, 1998, p. 11) Recently, a decision has been made to not re-open the landfill, reinforcing our belief that increased awareness of the hazards posed by wildlife can effectively influence decision makers.

Conclusions

Although the increased vigilance of airport operators combined with new government legislation may result in fewer bird strike and other wildlife incidents, it is still important to maintain an aggressive awareness program in order to encourage all decision makers associated with the aviation industry to consider bird hazards more diligently in the decision making process. To this end, we at Transport Canada have continued to maintain our existing awareness program and are constantly on the lookout for methods to make it more effective and aggressive.

The evidence suggests that stakeholders are becoming more aware of the hazards posed by wildlife. Currently, our goal is to maintain and improve the existing campaign. Quite often successful operations or ideas are implemented and then eventually abandoned or allowed to become obsolete. An awareness campaign, especially one involving aviation safety, needs continuous updating and must be proactive rather than reactive in order to maintain its effectiveness.



The Royal Jordanian Air Force Conflict between Birds and Aircraft

Colonel Malik Salamah Habashneh
Chief of the Flight Safety Branch, Royal Jordanian Air Force

The R.J.A.F has worked hard in raising flight safety standards in all its units. This was demonstrated through the remarkable decrease in the number of aircraft accidents during the last three years, and is the outcome of effective accident prevention programs, which were put into operation by dedicated personnel at all levels.

The safety branch is organized as follows: the director of air operations is the superior authority; the chief flight and ground safety branch is under its supervision, including the investigation staff and flight safety staff. The later includes the ground safety staff. The objectives of the flight and ground safety branch are:

a. To eliminate the number of flight accidents (Cat-5), or at least minimize it to below one per 100,000 flight hours.
b. To reduce the number of minor incidents and bird strikes to a minimum.
c. To enhance awareness to flight and ground safety by all the members of the R.J.A.F.

The main duties of the flight and ground safety branch in R.J.A.F. are:

a. The implementation of preventive plans- the branch is responsible for implementation of accident prevention plans in all units.
b. Supervision of the implementation of flight and ground safety policy.
c. Publication of annual flight safety reports.
d. Publication of monthly newsletters concerning flight and ground safety.
e. Establishment of programs for flight safety orientation to all units.
f. Advising the Directory of Air Operations about safety matters.

Some of the achievements of the flight and ground safety are:

1. Continuous improvement of accident prevention programs.
2. Promotion of flight safety, education and publicity. (The flight safety organization must not only gather information, but also disseminate it).
3. Maintaining a comprehensive data bank of all accidents.
4. Study and analysis of flight safety data, based on the comprehensive recording system.
5. Accurate and full report of all incidents, which lead or might lead to accidents.
6. Exchanging of information between military and civilian flying organizations in Jordan which face similar accident problems.
7. Following up on the accidents and defining reasons, resulting in a reduction in the number of accidents caused by similar factors.
8. Directing concerned personnel in all accidents, to avoid repetition of accidents in the future.

9. Distributing monthly flight and safety newsletters.
10. Conducting quarterly safety meeting in all units, in which the causes of accidents, prevention measures, and applied safety procedures are discussed.

The "problem" with birds started when we began sharing the skies with them many years ago. The first recorded bird strike on an aircraft occured on the 7th of September, 1908. That day, Orville Wright was flying several complete circles near Dayton, Ohio, during which he chased a flock of birds and killed one. The first death of a pilot from bird strike was that of Col. Rodgers in 1912 at Long Beach California, when a gull lodged in the flying controls of a wright flyer. Col. Rodgers was the first pilot who flew across the USA.

ICAO began collecting bird strikes data in 1965, and in 1980 the ICAO developed bird strike information system (IBIS), with the aid of a group of experts. IBIS is a reporting system designed to collect and disseminate information on bird strike aircraft to inform states of the danger posed to aircraft by bird strikes.

During the last five years R.J.A.F suffered twelve bird strike incidents. The aircraft affected were one F-1, eight F-5, three casa 101. No helicopters or military transport aircraft were affected. All accidents happened at low level, below 1000ft, and in training areas, while no bird strike incidents happened in the vicinity of air bases. Seven incidents took place in April and May, two incidents took place in September, two in January and Febuary, and one in November. According to this, 60% of all incidents happened in spring time, which is the season of migration.

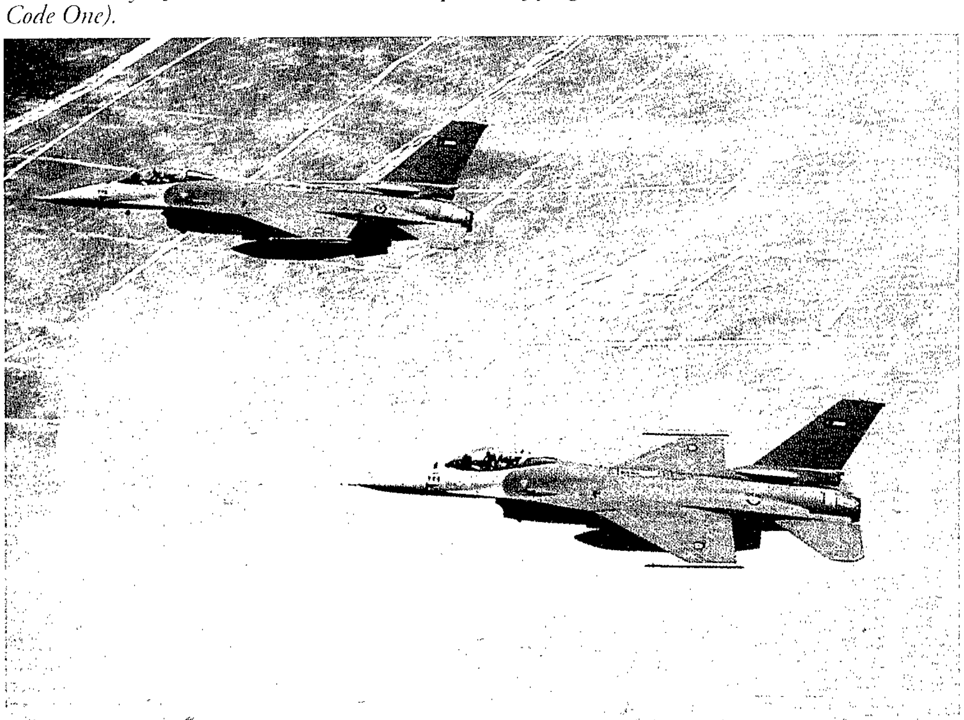
Accordingly, the safety branch in the R.J.A.F. issued the following instructions and directives, concerning bird strike accidents, which normally took place at a known period of the year:

1. Minimize low level flying in April and May.
2. Avoid the paths and areas of migrating birds while passing through Jordan.
3. Apply the proper procedures when encountering birds.

We must keep in mind that we are the intruders and we are invading the birds world.

Above: *Royal Jordanian Air Force F-16s on the track (Photo: Eric Stijger, Code One).*

Below: *A Royal Jordanian Air Force F-16s squadron flying over Jordan (Photo: Eric Stijger, Code One).*



Above: *RJAF F-5 in low-level training (Courtesy: RJAF)*

Below: *White Storks on the way south (Photo: Ronen Venturi)*

Bird Strikes and Flight Safety in the Turkish Air Force

Major Muzaffer Kauci
The Turkish Air Force

Introduction

In last 15 years, the Turkish Air Force has lost one pilot and two aircraft because of bird-aircraft collisions (Figure 1) and important civilian aircraft damages have been recorded, which resulted in forced landing emergencies. These accidents proved that spending money on preventing birdstrikes is one of the challenging aspects of flight safety in order to save lives and aircraft.

As a first step to achieve this goal, types of birds are identified, habitats, breeding and national reservation areas are located, seasonal and daily local movements are observed, migration routes are determined and finally all information is collected to form the bird maps over Turkey and around the bases.
Types of Birds:
The birds mostly encountered in Turkey are categorized into two groups (Table 1).

Table 1: Local and migrating birds in Turkey

Local Birds	Migrating Birds
Hawk	Goose
Falcon	Stork
Eagle	Crane
Pigeon	Starling
Owl	Heron
Crow	Mallard
Raven	European coot
Bat	Swallow
Turtle Dove	Pelican
Skylark	Quail, etc.
Sparrow, etc.	

Migration Routes

Since Turkey is a bridge between Europe, Asia and Africa, most of the migration routes pass through Turkey from north to south and south to north as shown in Figure 2.

- Geese stay in north Europe during summer, come to Turkey in winter.
- Quails start their journey from east Europe, pass through Black Sea, Turkey, east Mediterranean Sea and complete their trip at Africa.
- Honey buzzards (Pernis apivorus) begin their flight from East Europe, fly over Caucasia,

East Turkey, Syria, Israel, Egypt, and reach Africa.

- Storks migrate from central Europe, fly over Thrace, the Dardanelles and the Bosphorus, Lakes Area, Iskenderun Bay in Turkey, Syria and Israel and Egypt, ending their migration in South Africa. They are very dangerous since they fly in large numbers.

Breeding areas:

East Europe and the north part of Turkey are the incubation areas, south and east Africa are the winter habitation areas for birds (Figure 3).

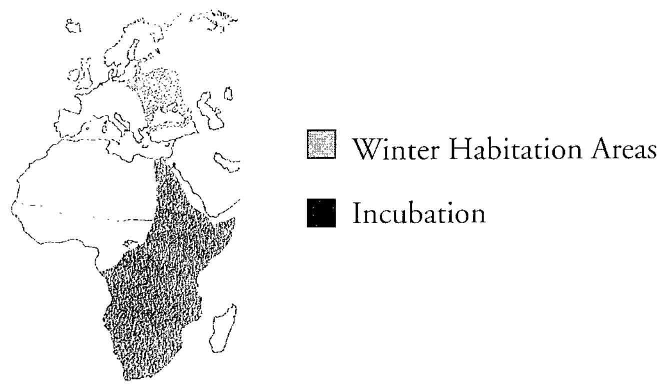
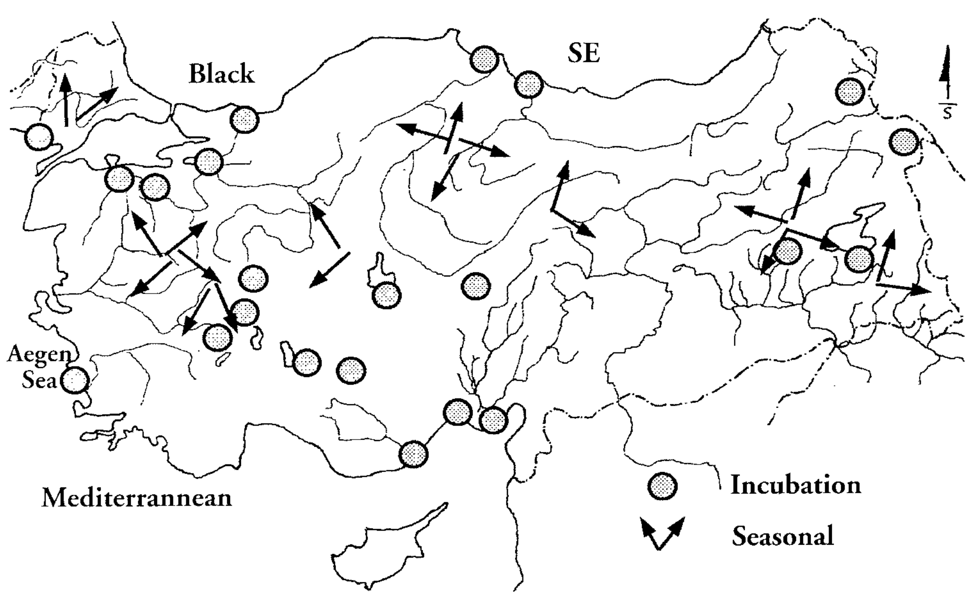


Figure 3: *Winter habitation and breeding areas.*

Also there are other breeding areas widely spread over Turkey since the landscape is surrounded by sea on three sides. Additionally, Turkey has a warm climate, large lakes, newly built dams, national parks, and forests (Figure 4).

Figure 4: *Main breeding areas.*



- *Bandırma National Park - Flamingo and other water birds,*
- *Gala Lake – Geese, mallards, bald ibis (Geronticus eremita)*
- *Dalyan - Cettia cetti*
- *Delta of Göksu - One of the most important habitation areas in winter and summer*
- *Eregli Reedbed - Pelicans*
- *Sultan Reedbed - Important breeding area*
- *Erçek Lake - At the end of breeding season, little grebes (Tachybaptus ruficollis) meet in very large numbers*
- *Arhavi and around - Migration of extensive numbers of birds of prey can be observed during September and October*
- *Delta of Bafra - During migration period large numbers of mallards and geese are observed and in summer breeding area for cranes*
- *Kızılcahamam Soguksu National Park - Storks and black vultures.*

Seasonal Movements:

In summer season, breeding areas and bird movements are widely spread over Turkey (Figure 5).

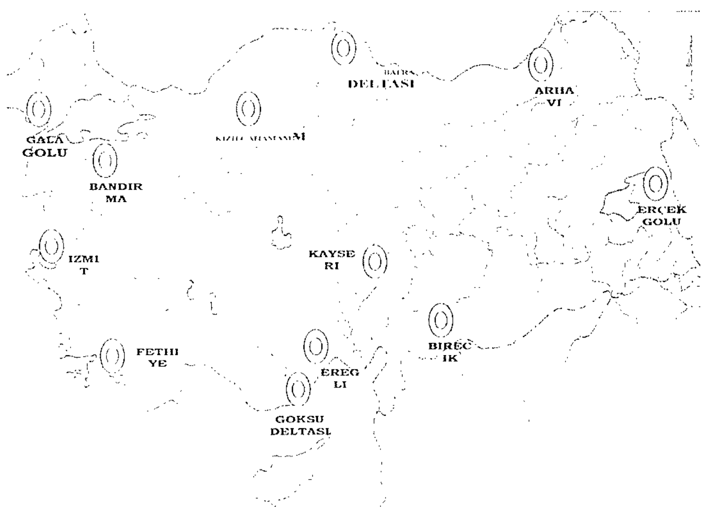


Figure 5: *Summer movements and breeding areas.*

In the winter season, birds move mainly toward the habitation areas, as shown in the months of December and February (Figure 6).

Spring is the season when dense bird activity is observed. Birds mostly fly to East Europe to breed. The area between Adana, Çukurova, Seyhan, Ceyhan and Iskenderun is the center where three main migration routes are separated from south to north (Figure 7).

- First route: to the west, through Lakes Area, Istanbul, Thrace
- Second route: to the north, through Yesilırmak, Kızılırmak
- Third route: to the east, through Southeast Anotalian area, Van Lake

In autumn, the birds fly back to hot areas in Africa following the spring route in the opposite direction over Turkey (Figure 8).

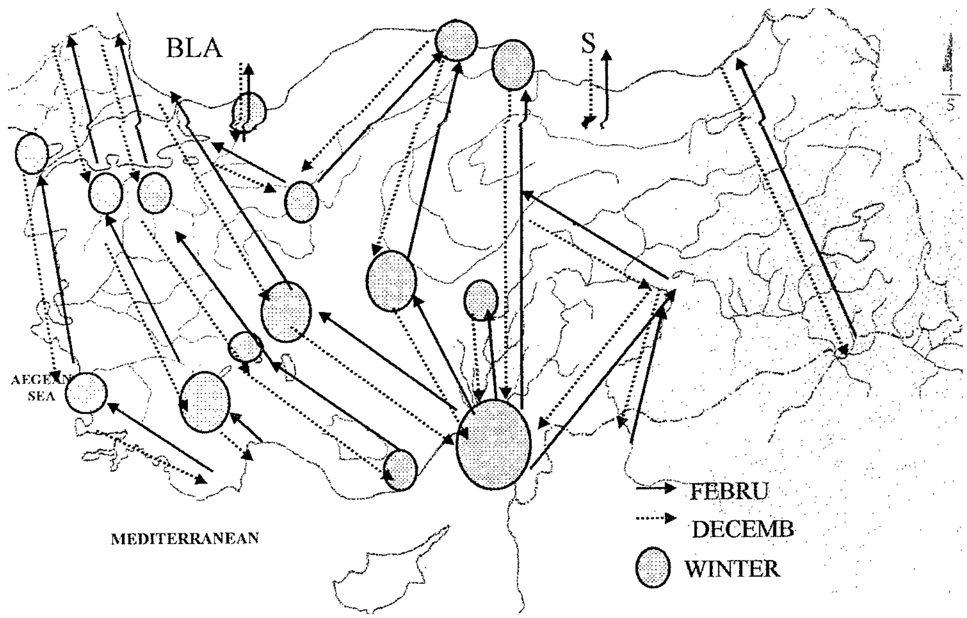


Figure 6: Winter season movements and habitation areas.

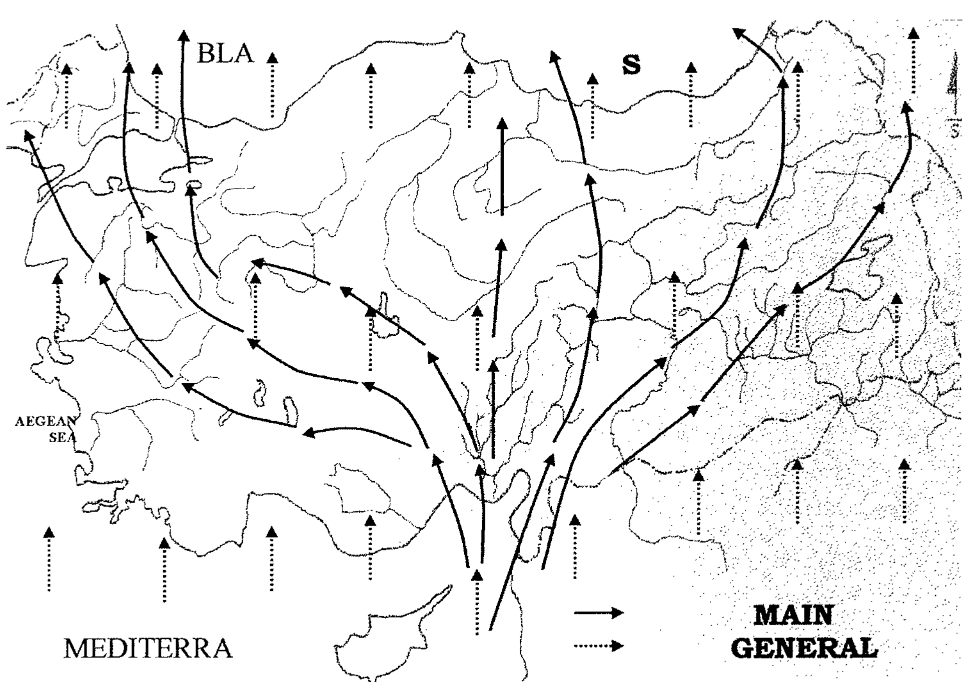


Figure 7: Spring season migration routes.

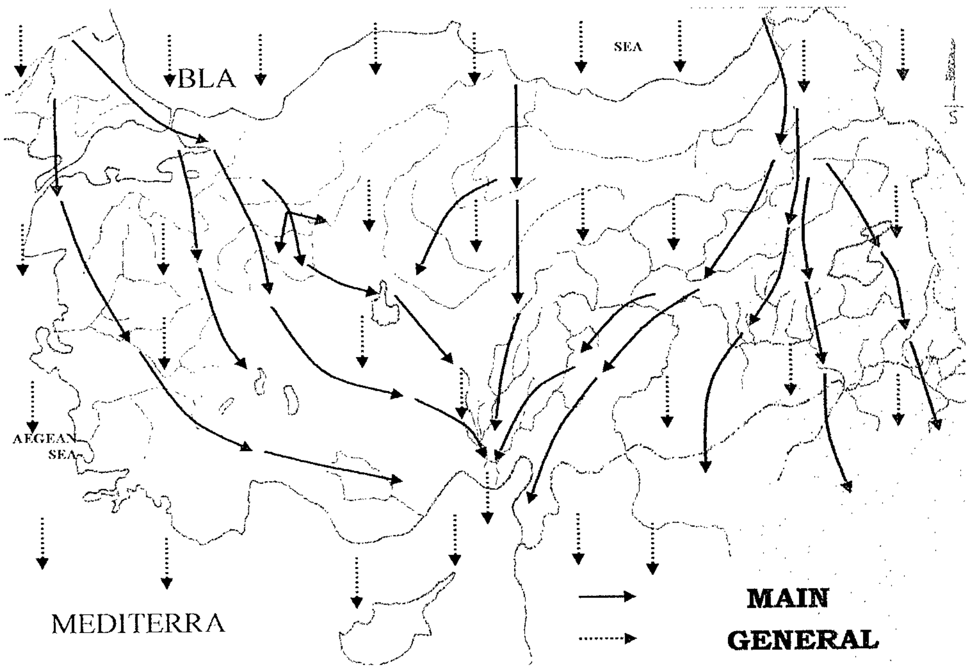


Figure 8: Autumn season migration routes.

Each season, very dense bird activity can easily be seen over Turkey. These seasonal movements should be followed carefully and all necessary action should be taken seriously for to achieve maximum degree of flight safety to minimize birdstrikes.
Bird Aircraft Collision Statistics:
Statistics of the last ten years are presented in Table 2.

Table 2: Bird-aircraft collision numbers.

Year	Takeoff	Airborne	Landing	Unknown	Total
1988-1989	3	19	8	-	30
1989-1990	5	41	4	-	50
1990-1991	9	32	10	-	51
1991-1992	4	22	12	3	41
1992-1993	6	19	7	3	35
1993-1994	5	22	8	1	36
1994-1995	4	14	12	4	32
1995-1996	3	22	9	6	40
1996-1997	2	14	2	5	23
1997-1998	1	29	1	6	37

The number of strikes during takeoff (Table 3) and landing (Table 4) phases are decreased successfully by following most of the harassing techniques accepted worldwide. Actually, total flight hours are increased each year and all the tables do not present the ratios. It is obvious some progress has been made, but some work still has to be done to decrease the numbers of airborne strikes to the tolerable limits (Table 5) .

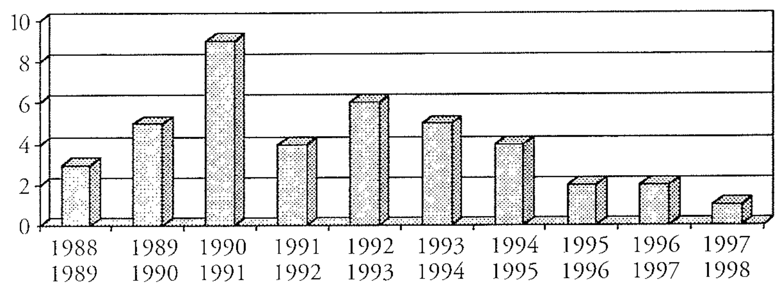


Table 3

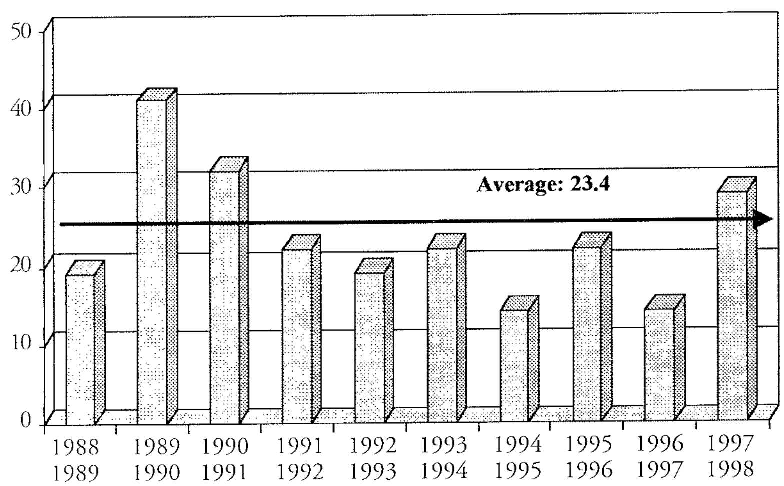


Table 4

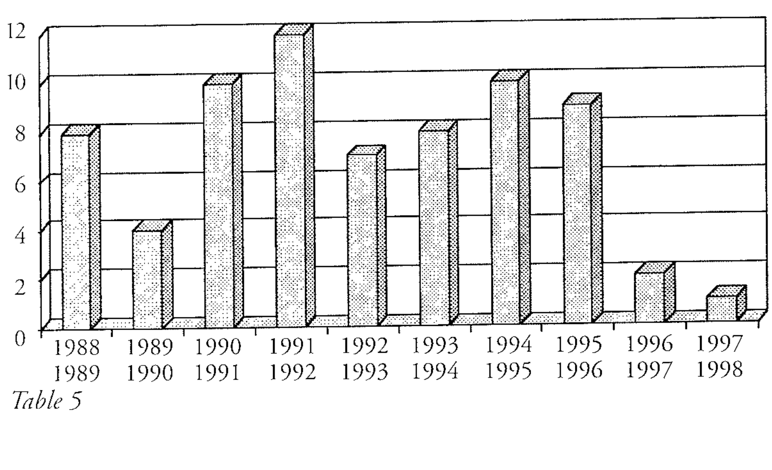


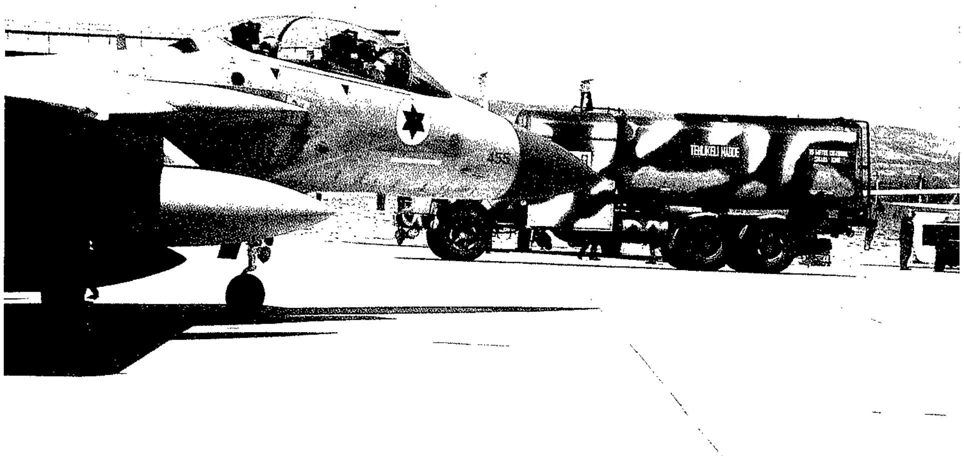
Table 5

Above: *F-16 of the Turkish Air Force just Landed in the IAF base, Israel. Regulation orders in Hebrew (Photos: Amir Modan, IAF Magazine)*

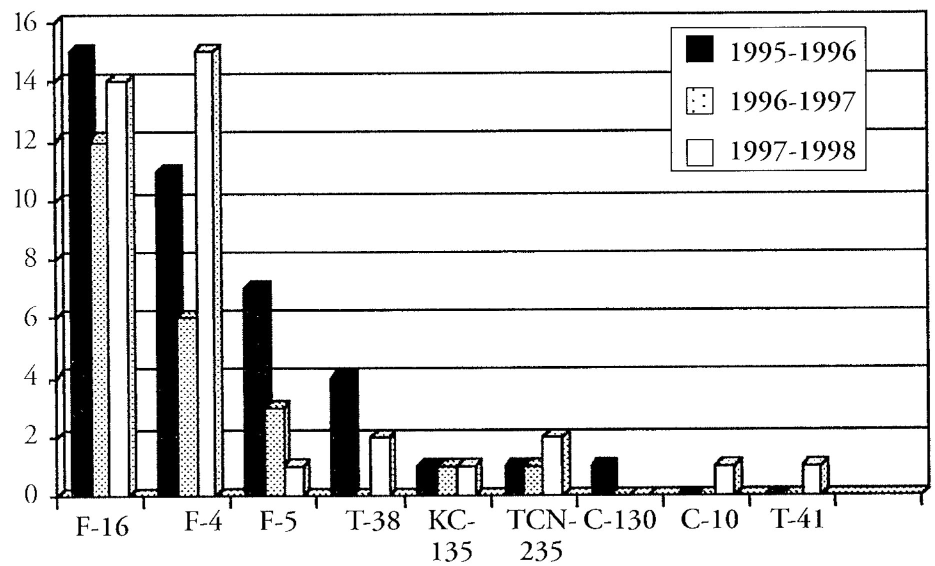
Below: *Joining forces between the Turkish and the Israeli Air Forces in an IAF air base*

Above: *A Turkish Air Force Seargent is watching an Israeli F-16 just landed in Turkey (Photos: Amir Modan, IAF Magazine)*

Below: *Refueling of an IAF F-15 with a Turkish tanker in Turkey*



The statistics of the last three years grouped by types of aircraft are presented in Table 6.



As can be noticed easily, types of aircraft that had the most birdstrikes are F-16's and F-4's. Actually, F-16 and F-4 flights constitute most of the hours and low level flights compared to the other aircraft, but on the average the number of birdstrikes with F-16s is a little bit higher. From these results it may be concluded that color, shape, and size of the aircraft might be an effective factor. Still, some more information and results of scientific observations performed by experts are needed to get a clear picture.

Procedures Followed at Base Level:

Every part of Turkey has a different bird profile. Therefore, each base should prepare its own wildlife management plans, form qualified BASH (bird aircraft strike hazard) teams, record the dynamic nature of local and seasonal wildlife movements, cooperate with biologists and wildlife preservation groups, analyze all the information to schedule base flight activities, and train the personnel. This is a really difficult and time-consuming task.

In all bases most of the worldwide-accepted measures are followed;

- Moving the airfield to the recommended height (15-30 cm)
- Preventing the grass going to seed
- Chopper flights if extensive birds around
- Drying the areas where water accumulated
- No trees where birds build nests

• Planting pine trees
• Birds of prey
• Distress calls
• Models of human and birds of prey
• Industrial or agricultural fireworks
• Pyrotechnics (shellcrakers, bird bombs, screamers)
• Live ammunition
• Scheduling flight hours (sundown, sunset, daily, monthly, seasonally)
• Limited low-level flights during critical days (3000 feet AGL and above)
• Observation personnel (on tower and around the base)
• Bright, shiny tapes
• Bird Watch Condition Codes (red, blue, yellow)
• Removing garbage-dumping areas away from the airfields
• Sirens and noise
• BASH team activities
• Collection of information to form statistics

Mechanics of the Plan

All these base level precautions are taken into consideration by a Bird Aircraft Collision Avoidance Committee, which determines their areas of responsibility under Turkish Air Force Regulations regarding standard flight safety rules. This committee has monthly meetings consisting of base and squadron flight safety officers and the other air field management personnel and chaired by the Base Operation Commander. They should form their Management Control Plans annually considering the bird activity profile around the base. They should carefully examine following subjects;
• Flight routes
• Flight altitudes
• Habitats
• Fight times and periods (daily, seasonally)
• Thermal currents
• Geographic formations (lakes, rivers, sea sides)
• Agricultural areas
• Garbage-dumping areas
• Breeding areas
• Migration routes

Bird Watch Condition Codes

Yellow, blue and red color coding system is employed at the bases to announce the degree of birdstrike hazards to the pilots to take necessary action. (Table 7)

Table 7: Bird watch condition codes

Yellow	Bird activity creates no danger
Blue	There are birds around that may create a hazard Pilots should pay extra attention to the birds No formation landings and takeoffs Landing lights on Low level flights are not recommended
Red	Extreme amount of birds No takeoffs Change altitude at least 3000 feet above ground Plan direct approach, fullstop landing

Also, all base operation personnel tasked for harassment of birds take the necessary actions to alleviate the hazards.

Conclusions

What we should learn from birdstrike hazards:

- Knowing and understanding birds
- Following safety rules strictly
- Dynamic measures
- Allocatong funds.

Actually, all available new information, tools and techniques should be imported and employed dynamically. More detailed local maps showing bird movements and statistics that give useful information should be prepared to lessen birdstrike hazards around the airfields. Departure patterns, air corridors, and even instrument approach should be revised, at least to avoid dense bird migration routes.

Avifauna Management Policy of the Hellenic Air Force

Maj. General D.Athanasakos
Inspector General of the Hellenic Air Force General Staff
Messologion St. 15551, Athens, Greece

This paper deals with the influence of Greek avifauna on the flights of HAF A/C, the aspects of the problem that the HAF faces, and the measures taken to avoid birdsrikes.

The ornithological situation is closely related to the geographical position and profile of Greece as well as avifauna management policy. Greece covers an area of 132.000 square km., occupying the southern edge of the Balkan peninsula. It is therefore a part of the Mediterranean bird migration knot to and from Africa, with April, September and October the peak months of migration. The climate of Greece is determined by latitude, ground profile and the large sea areas surrounding the land, making the country a perfect place for bird wintering and breeding for many species as: white pelicans, dalmatian pelican, flamingoes, herons, swans, ducks, geese, eagles, hawks, vultures, storks, rooks, gulls, cormorants, swallons, turtle doves, lapwings and starlings.

Greece is characterized by its rich variety of form, resulting in three main bird-habitat categories:

1. Coastal ecosystem. The 15.000km long coastal line is of great importance for birds and this is made apparent by the fact that 1/3 of the main area of bird assembly is on the coastal zone. The coastal bird habitats include coastal wetlands, strands, and cliffs, which cover 70% of the Greek shores, where Peregrine Falcons, lanners, Eleonora' s Falcons (a species unique in the world) and thousands of Gulls are nesting.
2. Wetlands. Some of the largest and most significant wetlands in Mediterranean area, are situated in Greece, such as Evros Delta, Nestos Delta, Kerkini, Volvi, Vistonida, Koronia, Small and Large Prespa Lakes, Porto-Lagos, Mesolongi, Etoliko lagoons, and Amvrakikos Gulf.

Greek wetlands per category are as follows :

Wetland type	No of sites	Total Surface (ha)
River Deltas	12	68,000
River Mouths	42	4,200
Lagoons	60	28,700
Marshes	75	5,830
Lakes	56	59,700
Reservoirs	25	35,820
Springs	17	133
Rivers	91	4,268 kms

A significant number of rare endangered bird species, such as the Dalmatian Pelican and the Slender-Billed Curlew, inhabits all the above wetlands.

3. Forests. According to the national forest inventory of 1992, 49.3% our country is covered by forest areas. It should be noted that the flora of Greece is the second richest in Europe next to the Iberian peninsula. Despite the relatively small area of Greece, more than 6,000 plants have been recorded and as a result a lot of bird species inhabit in the forests. Some of them, such as the Imperial Eagle and the Black Vulture are very rare in Europe.

The main factor in maintaining our country's ornithological situation, is the development of a proper management and protection policy for our ecosystem. Greece has adapted a nature protection framework, with the implementation of the following seven international agreements and/or instructions, and two international programs:

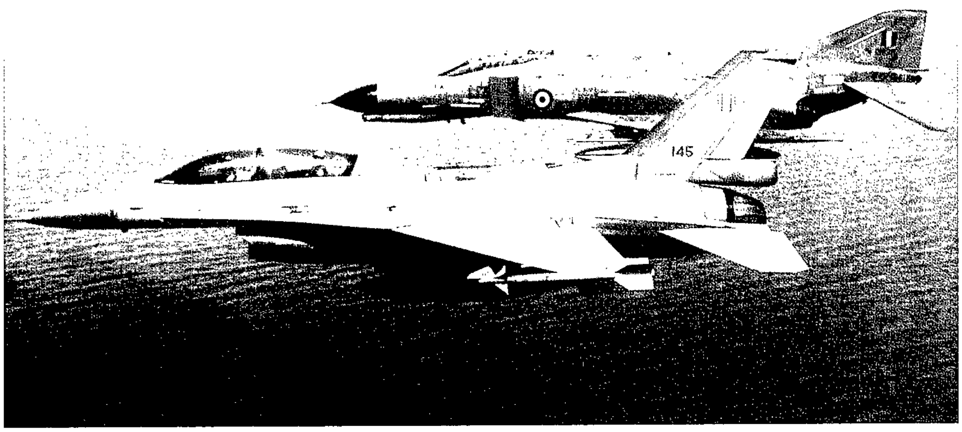
1. Ramsar Convention
2. Bonn Agreement
3. Agreement for the protection of international cultural and natural heritage
4. Bern Agreement
5. Eur.Com. 79/409 Instruction
6. Eur.Com. 92/43 Instruction
7. Barcelona Agreement
8. Unesco special program
9. Biogenetic park development program

In our country there are 11 wetlands of international importance (Ramsar Convention), 10 national parks (1 biogenetic) of a total area of 95000 acres and one sea park on Alonisos Island. It should also be noted that Greece has the strictest hunting laws in the European Union. Despite the above measures, the level of maintenance of the ornithological situation in our country is not satisfactory yet. This is caused by illegal actions in the protected areas, such as the turning swamps to cultivated area, uncontrolled use of pesticide, forest fires, etc.

With the prevalent ornithological situation, the rather small Greek airspace is used daily by thousands of gulls. Especially during migration months, the migration routes are full of small and larger birds flocks and for this reason a lot of air accidents have been caused by bird strikes. More specifically, from 1974 until today, 121 bird strike accidents occurred in HAF, three of them Class A accidents in which aircraft were destroyed. HAF, in trying to face this problem but with respect to state institutions for avifauna protection, has taken the following measures for Bird Strike Accidents Prevention:

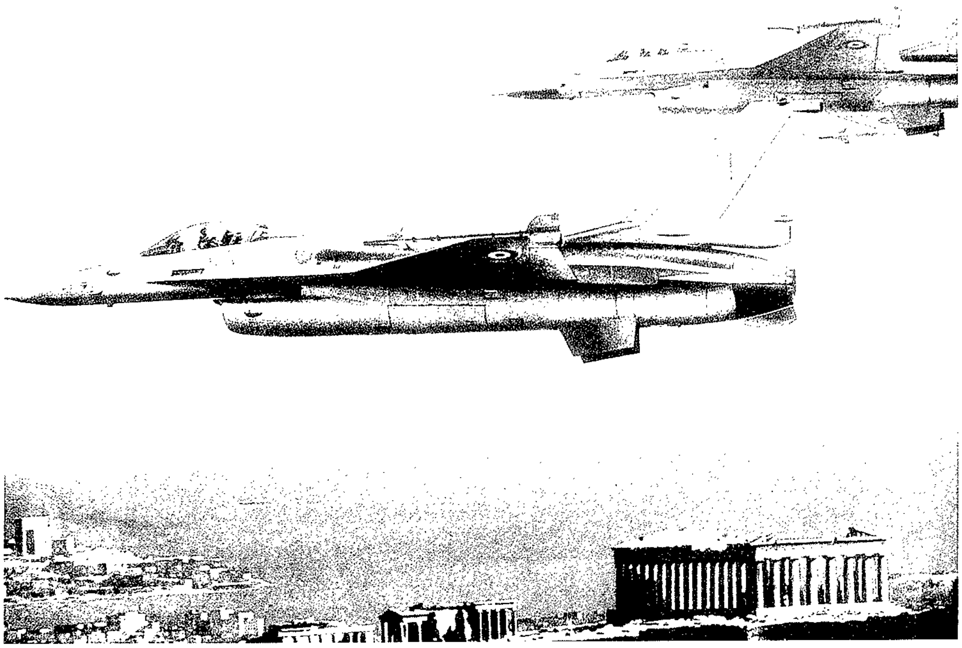
1. Proper air crew briefing

Aircrews are briefed to avoid flying below 2000 ft and especially under 500 ft, during bird migration periods. We have observed by radar that birds fly above the Aegean Sea



Above: *F-16 and F-4 of the Hellenic Air Force training over the Mediterranean Sea (Courtesy: HAF)*

Below: *HAF F-16 collided with a bird (Courtesy: HAF)*



***Above:** HAF F-16 flying over the Acropolis (Courtest: HAF)*

***Below:** A/C type M-2000 (HAF) after take-off. In altitude 300 feet with airspeed 240 knots a bird strike occurred, followed by a loud noise from the engine compartment with simultaneous smoke in the cockpit, loss of thrust and flames at the empennage of the engine. The a/c immediately lost altitude and the pilot successfully abandoned the a/c which was destroyed on the ground.*

at the height of 4000 - 6000ft, although in windy conditions the height of bird flights is differentiated as follows:

a. With adverse wind, birds fly at very low altitudes.

b.With favorable wind, birds fly at high altitude.

The migration routes and areas with large bird concentration are known to aircraft crews and taken into consideration during mission planing, for the avoidance of these areas. In cases that avoidance of bird concentration areas is inevitable, crossing is made in height greater than 3000ft. Also crewmembers, in cases that a bird strike is imminent, should try to avoid the birds by decreasing power and lift of the aircraft. In all cases helmet glasses have to be used during flight and aircraft landing lights to be on during landing. In case of bird concentration in the airfield, air traffic control has to inform the aircraft crews and aircraft landings are to be made individually (not in formation), using Long Final approach and five minutes separation. Also, if possible, a change of runway may be ordered.

2. Statistical Data Elaboration

The statistical data are continuously enriched from our own sources (observations, accident analysis, etc.), with data from other air forces, with which we are already in cooperation, and from the knowledge that we gain with our participation in the Europe Bird Strike Committee. HAF is trying to collect information for bird movement and concentrations, in order to develop its own "BIRDTAM NET" using Airport Approach Radars, meteorology, aircrew reports and information from ornithologists. Since all of the above information are received in real-time, prompt informing of the aircrews will be possible through NOTAMs. The services of an ornithologist, joining the HAFGS Flight Safety Directorate will be considered very helpful in the development of our "BIRDTAM NET". Finally, in addition, HAF has established a special committee for bird strike accident prevention.

3. Proper Management of Airfield and the Surrounding Areas

In cooperation with other state authorities as Environmental, Agriculture, Transportation & Communication Ministries, HAF has initiated the following steps:

a. Legislation of a minimum distance of 9km from airfields for the construction of dump sites and biological cleansing facilities with which local authorities should comply

b. Drainage of stationary or contaminated water of airfield and surrounding areas

c. Dealing with large bird concentrations in airports, under the instructions of the Environmental Protection Directorate

d. Establishment of proper cultivation in airport surrounding areas, according to State Agriculturists' instructions, in order to minimize bird concentrations in these areas

For the time being, we emphasize the wiping out of the causes of bird concentration in airfield areas. Most important of these are the search for food, water, shelter, and places for nesting. We can avoid all of these by removing garbage, prohibiting cultivation that produce spores, draining stationary water, cutting the grass in a height less than 20cm

and by covering possible nesting places using fishing nets on a/c shelters and hangar roofs. In case that birds are still trying to visit airport areas and influence by their presence flight safety in take-off and landing we take the following measures:

4. Implication of Bird Scaring Methods in Airports

We have used the most common methods such as, noise guns, scarecrows and dead bird dummies with nearly satisfactory results. More specifically:

a. Noise guns that are placed in all HAF airports, even though they are used in 5-10 min increments, so that birds do not get familiar with, they have no effect on Gulls which are No. 1 danger for bird strike air accidents.
b. Scarecrows which are moved in different places, do not seem to bother birds. Perhaps we do not use the right ones, that combine frightening looks with movement by the wind.
c. Dead gull dummies in some occasions are very effective, but we have noticed that they attract Rooks, Crows and Magpies if they are in the area.

Except the above methods, in some airports that have problems with Domestic Pigeons and Common Buzzards, that sit on signs besides runway, we use:

a. Traps, which have been proven very effective
b. Hunting in some extreme occasions, which even if it is very effective, we have to avoid it, in respect to the avifauna protection laws.

In order to improve the current situation we have implemented the following methods, in the framework of a pilot program:

1. Bird distress calls, with the use of electronic sound devices. Conclusions have not yet been drawn from their use, but it seems that their effectiveness shall be improved as we gain experience. We estimate that the best results can be obtained if we develop the capability of recording the distress calls of specific bird species that influence Greek airports and use them for bird control. We should note here, that the distress-call devices, available in the market, do not rebroadcast the voices of all bird species we wish to keep off our airports, such as Mediterranean Gull, Yellow-Legged Gull, Common Tern and others.
2. Use of Trained Falcons: We have already established a team of two falconers, and by the end of July 1999 we are going to procure 11 hawks and falcons, on order from a breeding center in England. At the same time this team will be reinforced with personnel that will become the core of the future Falconry Center of HAF. Those falcons do not need to hunt other birds because as it is well known, only the presence of a falcon in an airport area is enough to keep all birds in a considerable distance ensuring safe take-off and landings.

We know that none of the above methods by itself is a panacea, but the combination of two or more will bring satisfactory results, a continuing ambition of HAF.

There is an Air Force saying "The skies are ours". We should not forget though, that birds were here first and have equal rights on airspace. Problmes - and accident-free co-existence with birds is possible by taking proper bird-control measures, cooperation, and exchange of information and experience.

United States Air Force Europe Bird Strike Hazard Reduction

Maj. Gerald Harris
United States Air Force Europe

Introduction

The United States Air Force Europe (USAFE) has a variety of bases, which extend throughout Europe, Africa, and the Middle East. With flight operations spanning such a variety of environments and climates, birdstrike reduction efforts are quite a challenge. The Air Force publishes general guidelines, which describe how to set up a basic Bird Air-Strike Hazard (BASH) program. These guidelines are not all-inclusive but provide a foundation on which to build an effective program. Each base then builds upon this basic document to develop an effective bird strike reduction program based upon each bases particular bird problems. Birds aren't the only problem, there are other animals that can be hazardous to aircraft, including deer, foxes, dogs, pigs, etc. Instead of a birdstrike reduction program, a more appropriate name might be "wildlife management program". One of the key factors in determining how to conduct an effective program is environmental control. Determine what makes the airfield environment attractive to birds, and other animals, and reduce the attractiveness as much as possible.

Bird Strike Statistics

Why is the Air Force so interested in having a BASH program? We have lost 33 aircrew and 14 aircraft in the past 12 years due to birdstrikes. The average cost to the Air Force is 36 million dollars per year. And it's not only fighters which have had fatalities due to birdstrikes. The accident that really caught our attention was the E-3 AWAC's crash on takeoff in Elmindorf Alaska. It showed that not only small fighter aircraft were vulnerable to birdstrikes, but also large multiengine aircraft were susceptible catastrophic birdstrikes. What can we do to help reduce these numbers? If you look at the statistics, the Air Force has recorded over 33,000 bird strikes since 1985. That averages out to approximately 2600 bird strikes a year. Twenty-nine percent of all birdstrikes are unknown to the crew and are not discovered until after flight. If you take out the unknown bird strikes it turns out that 65% of all birdstrike occur in the air field environment (Figures 1 & 2). The second largest phase of military flight involving bird strikes is low-level with 23% of the known strikes. These are military aircraft flight statistics which include low-level training at the altitudes most bird strikes occur. Commercial aircraft typically do not fly low level, below 1000 ft AGL, which means that an even higher percentage of their bird strikes occur around the airfield. The good news is that this is the environment that we have the most control over. We can manipulate the airfield environment to make it less attractive in order to reduce bird populations in these areas.

It is important to know that bird strikes occur at different rates depending on the time of year. The majority of bird strikes occur during the two primary migration periods: during the fall migration, (September and October), when birds fly north to south, and during the spring migration when migrating birds return north during the months of April and May. It is also important to realize that the least number of birdstrikes occur during the winter months of December, January and February. Knowing the migration seasons and tracking the migration routes can allow flight crews to flight plan around known migratory routes and reduce their risk of birdstrikes. The migration routes are particularly important to know because the majority of migratory birds are the larger bird species which if hit can cause significant damage to aircraft. These include geese, ducks and storks.

Another interesting statistic concerns the altitudes at which bird strikes occur. Figure 3 shows that the vast majority of bird strikes, 66%, occurred below 500 feet Above Ground Level (AGL) and 80% of all bird strikes occur below 1000 feet AGL. The less time spent below 1000 ft the less your chances are of having a birdstrike.

BASH Programs

In order to make the environment less attractive to birds and other animals you need to ask, what are birds looking for? A good analogy is the following: Birds are like teenagers - they are looking for three things. A place to eat, a place to sleep, and a place to breed. Understanding what is considered attractive or unattractive to birds will help you make environmental decisions to reduce their attractiveness of airfields to birds.

What can be done? Maintain grass height at 20 to 40 centimeters. Birds like to have a clear view around them so they can see predators approaching. If the grass height is kept high they will not land. Bare areas allow birds to clearly see predators, therefore they will land in these areas. Plant grass in these areas to reduce the bare spots. Trees attract birds for resting and nesting. Keep the airfield area clear of trees to reduce the areas for birds to nest and roost. Open landfills and garbage dumps attract birds. Do not place a landfill near an airfield or move landfills currently located near airfields. Standing water attracts birds. Eliminate standing water in the airfield environment if possible. Insure that drainage ditches do not hold standing water. Work with your environmental control folks to reduce food sources for birds around the airfield. This can include the use of insecticides and landscaping of the areas around the airfield.

Educating flyers on local bird populations, migration routes and current high-density bird locations adds additional information. Aircrews can then use risk management to determine when and where to fly. BIRDTAMs are notices to airmen informing them of known concentrations of birds during different times of the year. During the migratory seasons low-level routes should be varied to avoid known bird concentrations. Flight along rivers and waterways are reduced. Flight routes can be planned to cross perpendicular to peaks and ridgelines minimizing the hazard of hitting soaring raptors, which use the thermals over the peaks. Low level routes and altitudes are planned to avoid seasonal

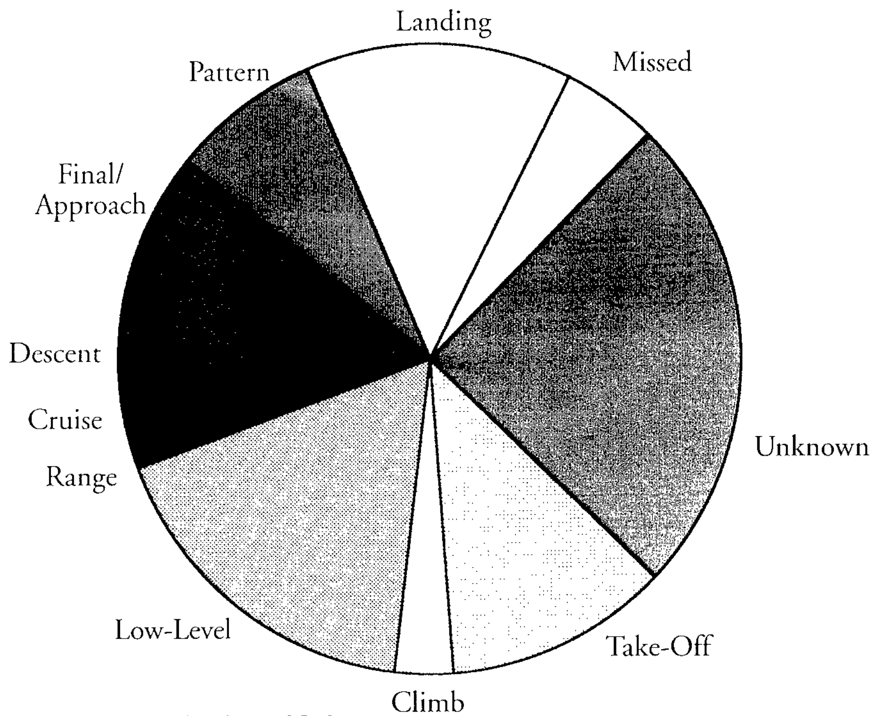
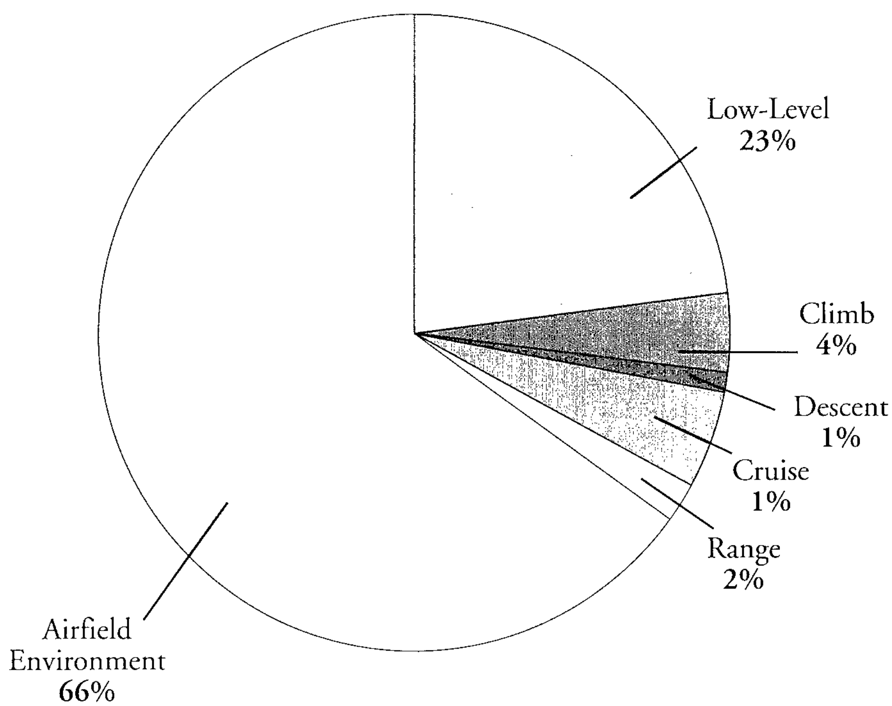


Figure 1: *Bird strikes by phase of flight*

Figure 2: *Bird strikes by phase of flight, without unknown category*



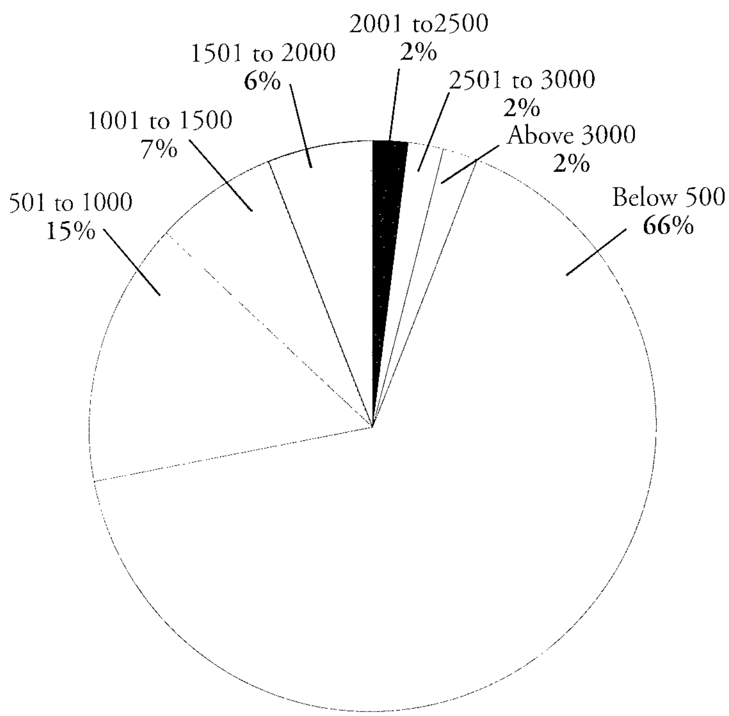


Figure 3: Bird strikes by altitude

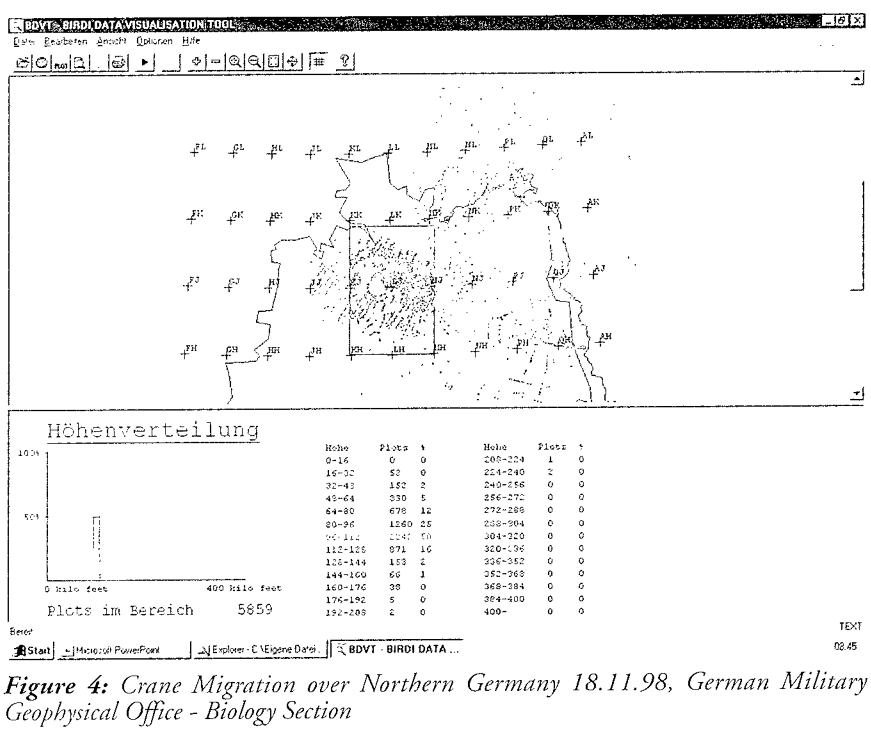


***Figure 4:** Crane Migration over Northern Germany 18.11.98, German Military Geophysical Office - Biology Section*

migration routes. Other options include setting minimum flight altitudes for specific legs of low-level routes and known roosting areas. When low-level routes become more hazardous due to bird migration, consider closing low-level routes on days that aircrews have reported high bird activity.

Real-time warnings can come from a variety of sources but often come from aircrew that encounter large concentrations of birds in flight and report them back to their home station. Information is passed on to other aircraft in that area and in some cases low-level routes are closed based on bird sightings from aircrew. The German Air Force uses an enhanced air defense radar system in conjunction with the German Military Geophysical Office to produce NOTOM's based on real time bird radar returns (Figure 4). The locations of birds are passed on to aircrews using a grid map system. Once high concentrations of birds are located, the aircrews are notified of the map grid section which is effected and flight through those areas is prohibited.

USAF uses local bird watch conditions to alert aircrew to bird activity around the airfield and restrict their flying during times of high bird activity. Bird Watch Condition codes are used to rapidly communicate changes in bird activity around the airfield.

Bird Watch Condition SEVERE: High bird population on, or immediately above, the active runway or other specific locations that represents a high potential for strike. Supervisors and aircrews must thoroughly evaluate mission needs before conducting operations in areas under Condition SEVERE. Immediate action is required to lower the threat.

Bird Watch Condition MODERATE: Increased bird population in locations which represent an increased potential for strikes. This condition requires increased vigilance by all agencies and supervisors and caution by aircrews.

Bird Watch Condition LOW: Normal bird activity on and above the airfield with a low probability of hazard. This condition will be in effect for the remainder of the flying day, whenever a severe or moderate condition has been declared and subsequently downgraded. Upon extended normal bird activity, no bird watch condition need be declared. Bird forecasts predict where migratory routes are and when birds will be using them.

Once birds have been sited around the airfield frightening techniques need to be employed to remove them from the airfield. Some types of frightening techniques include playing distress calls over a loud speaker system to scare birds from the airfield. Distress tapes are available for a variety of bird species.

Other techniques include bird-scatter guns, which fire a charge into the air. The round then explodes making a big bang, which startles the birds and causes them to move. The charge is fired so that it will explode over the top of the birds driving them away from the runway. Gas cannons are another dispersal method used that produces a loud noise and can be programmed to fire at specific times. To use gas cannons properly they need to be moved to different locations so the birds don't get acclimated to same sounds coming from the same area.

In some cases lethal methods may be required to reduce local bird populations. We employ gun clubs to come out to the airfield on prearranged airfield hunts. The hunters kill

the birds that could not be dispersed by other means. This is also effective for controlling other wildlife that is a hazard on the airfield, deer and rabbits for example. Before hunts can begin, we make sure we get the proper permits and that all hunters have been properly trained. Falconry programs have been introduced at many bases in Europe and are very successful, when used in conjunction with other methods, at keeping birds away from the airfield.

Conclusions

Why have BASH programs? Because birdstrikes kill people and damage aircraft, which effects your ability to maintain our forces. We know that birds want a place to eat, sleep, and breed, so we can deny them that by changing the airfield environment to make it as unattractive as possible. If we combine active controls like falconry, bird scatter cartridges and gas cannons we can further reduce the number of birds near the airfield.

By letting our aircrew know when birds are in the area, and by planning flights to limit exposure we can further reduce the risk of birdstrikes. Advances in radar systems are allowing us to see real-time bird movement and forward warnings to our aircrews.

Birdstrikes are a hazard that will always be there. We will never eliminate them entirely, but we can substantially reduce the risk of having a birdstrike by controlling the airfield environment, educating our aircrew, and continuing to develop technology that gives us real time bird location data.

Bird Remains Identification System (BRIS) - from a Bi-national to a Global Database

Judy Shamoun-Baranes
The Department of Zoology, Tel Aviv University, Tel Aviv 69978

Abstract

Since the beginning of the century downy barbules of feathers were found to have diagnostic characteristics that can be used to identify birds. Following collisions between birds and aircraft, small feather fragments are usually the only evidence that a bird was involved in the incident. One of the essential steps in reducing the hazard of bird strikes is properly identifying which species are involved and pose a higher risk to aviation.

The Bird Remains Identification System (BRIS) is an interactive multimedia program on CD-ROM for identifying feather remains. It is an innovative tool designed as part of joint project between Tel Aviv University, Amsterdam University, The Royal Netherlands Air Force, The Israel Air Force and the Society for the Protection of Nature in Israel. BRIS serves two main purposes: (1) it provides a reference database of feather microstructure images and descriptions for 200 palearctic species (2) it serves as an interactive identification system. The system also includes Geographic Information System (GIS) based distribution maps, as well as other tools. This system can also be used for ecological studies of predator feeding habits, forensic work and as an educational tool.

International cooperation played an integral role in the development of this system. BRIS's design makes it easy to expand to include more information such as the macroscopic characters of feather, or DNA fingerprints, as well as expanding the species list. Joining efforts to expand such a system can benefit air forces by saving them both time and money.

Introduction

Chandler (1916) was one of the first researchers to show that the microscopic structure of feathers has diagnostic characteristics that can be used to identify birds.

Bird strike statistics are an important tool for understanding and reducing bird strike hazards around the world. Therefore, one of the first steps in reducing the hazard of bird strikes should be to obtain reliable statistics by properly identifying which species are involved and pose a higher risk to aviation.

Following collisions between birds and aircraft, whether military or civilian, several techniques are available to identify birds involved in aircraft collisions. The simplest technique is unaided visual identification of bird remains found on runways during routine runway sweeps (Linnell et.al. 1996). Other techniques requiring expertise and laboratory assistance

include microscopic examination of downy barbules of feathers (Shamoun & Yom-Tov 1996, Laybourne & Dove 1994, Laybourne et. al. 1992, Brom 1991), electrophoretic identification (Ouellet 1994), and DNA examination (Hermans et.al.1996). Each technique has its drawbacks and benefits (Brom 1992).

One of the main advantages of expertise identification of bird remains is that they should sample a larger proportion of the birds involved in collisions and give a more reliable representation of the bird hazard. The Bird Remains Identification System (BRIS) is an interactive multimedia program on CD-ROM that was developed as a tool to assist in identifying feather remains from 200 species of birds from Europe and the Middle East. The design and use of this system is described in this paper.

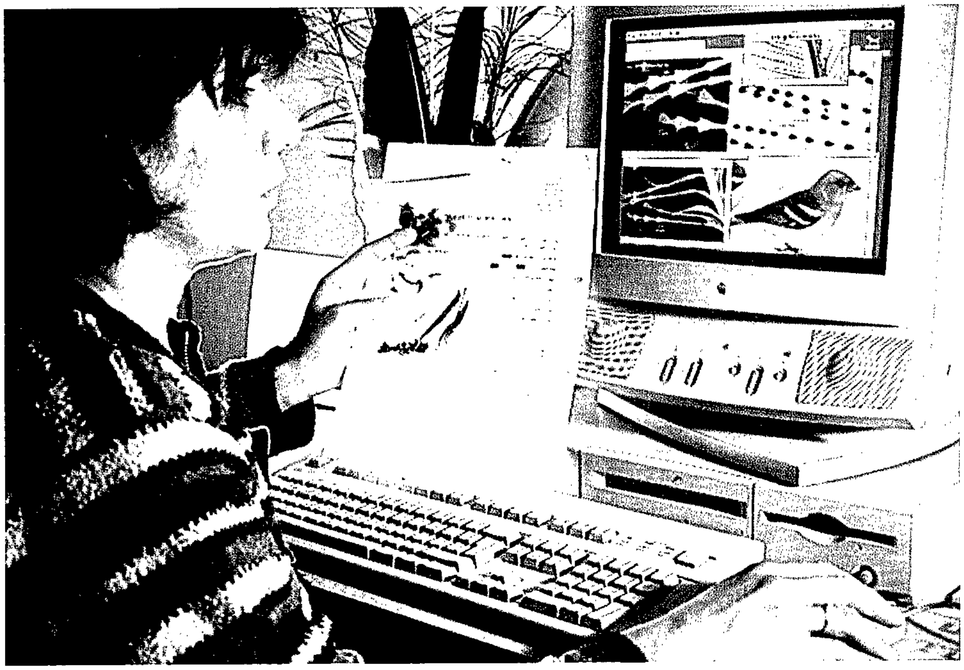
Materials and Methods

Bird Remains Identification System

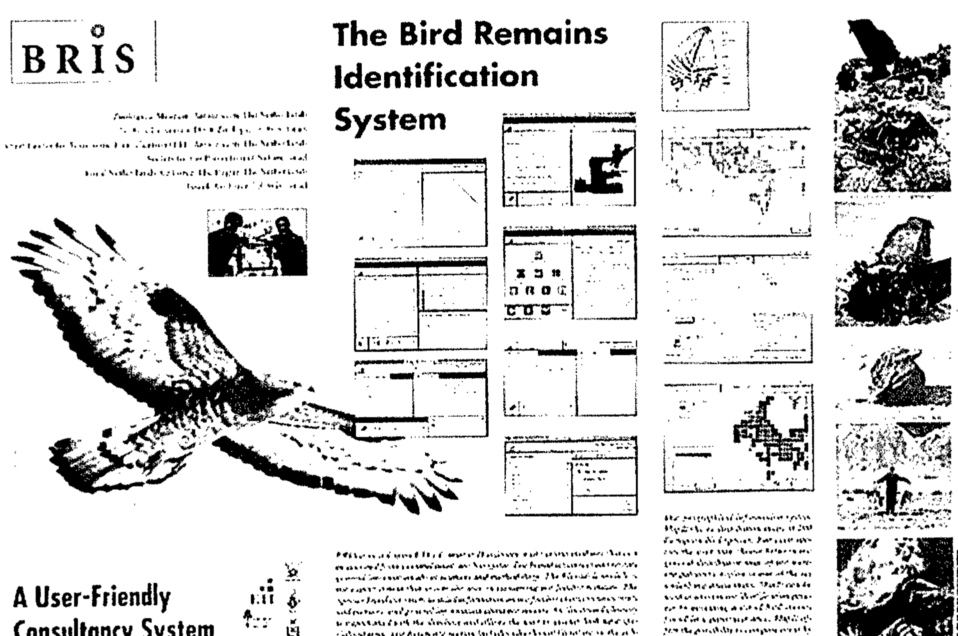
The Bird Remains Identification System (BRIS) is an innovative tool designed as part of joint project between Tel Aviv University, University of Amsterdam, The Royal Netherlands Air Force, The Israeli Air Force and the Society for the Protection of Nature in Israel. The software was developed by the Expert Center for Taxonomic Identification (ETI) in Amsterdam. BRIS serves two main purposes: (1) It provides a reference database of feather microstructure images and descriptions for 200 palearctic species (2) It serves as an interactive identification system. The system is based on ETI's Linnaeus II software and designed for both Windows and Macintosh platforms (Prast et al. 1996). The program is user-friendly with all components accessible through the Navigator and hyperlinked (figure 1). The reference database in BRIS includes the microscopic structure of downy barbules of feathers examined under both light and scanning electron microscope (Laybourne & Dove 1994). The database contains photographs of the feather microsctructures as well as textual descriptions of the feather structure and the species biology and ecology, an illustration of the bird as well as the bird's call. In addition to the expert identification system, "IdentifyIt", BRIS also includes "MapIt", a Geographic Information System providing distribution maps for each of the 200 species, as well as a glossary, an introduction with a short explanation on materials and methods, bird strike statistics, a reference section, and other tools.

Israel Air Force Bird Remains Identification

Since 1991, the Israel Air Force has conducted systematic identification of feather remains. Feather remains are collected at Israeli Air Force bases and sent to the Laboratory for Feather Remains Identification at Tel Aviv University, where they are identified by a combination of microscopic examination of downy barbules (figure 2) and macroscopic comparison with bird skins at the Tel Aviv University Zoological Museum. Feather remains are received along with relevant bird strike data such as time, altitude, area of birdstrike, and level of damage.



Above: *Judy Shamoun-Baranes, who is in charge of the Feather Remains Identification Laboratory, examining the remains of a feather with the help of a computer program developed jointly with Holland (Photo: Lior Rubin).*
Below: *The CD-ROM, with 200 common birds mapped from Europe and the Middle East allows relatively rapid identification of feather remains in case of accidents.*



__Above:__ This scanning electron microscope photo of a Long-eared Owl feather enlarged 1000 times was prepared at the Feather Identifacation Laboratory run jointly by the Israel Air Force, the Society for the Protection of Nature in Israel and Tel Aviv University, in cooperation with the Royal Netherland Air Force and Amsterdam University, ETI (Photo: Professor Tsvi Malik)

__Below:__ September 7, 1997: an F-16 crashed over the Ramon Crater, Negev, Israel, because of a Honey Buzzard which penetrated the canopy, hit the face of the pilot in the back seat. The pilot bailed out and the one in the front seat was badly wounded and lost his leg. These are the remains of the canpoy with small feather remains, which was identified by Judy Shamoun-Barenes. (Photo: courtesy IAF)

The techniques used to develop the BRIS database have been used successfully for feather identification in the Israel Air Force since the early 1990's. However, bird remains are occasionally identified on the airfields by the bird control units or by the pilots during flight, without being sent to the laboratory for verification. Following, is a short description of the birdstrike statistics for 1991-1997, comparing the results of feather remains identification by Bird Control Units and air crew, not verified by laboratory examination, to a summary of all feather remains identified, combining laboratory as well as field analysis. A combination of field and laboratory identification should provide the most accurate assessment of the species involved in all bird strikes, as well as sample a larger proportion of the bird strikes. Remains were identified for a total of 527 bird strikes, 144 of which were identified in the field without laboratory analysis.

Results and Conclusions

Only 18 species were identified in the field compared to 90 species identified when combining field and laboratory analysis. When analyzing the various orders involved in birdstrikes (figure 3), several interesting trends are apparent. Only 18% of the birdstrikes identified in the field were caused by passerines (Passeriformes), compared to 33% identified by both methods. A similar trend was seen with the swifts (Apus sp.), 2.8% of the bird strikes were identified as swifts in the field, compared to 10% by both methods combined. This same increase in proportion of passerines and swifts using a combination of microscopic and macroscopic identification was also shown by Brom (1992) for north-western Europe.

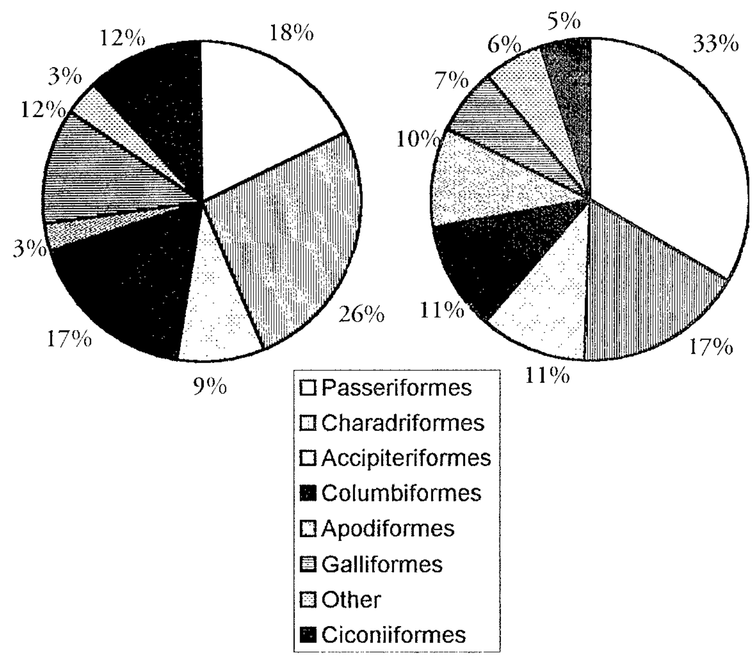


Figure 3: *Percent of avian orders involved in bird strikes identified by various methods 1991-1997: (A) in the field (n=144) and (B) in the laboratory and/or field (n=527)*

Charadriiformes, Galliformes and Columbiformes were all overestimated by field identification. These groups are overestimated because they include the species commonly found on air force bases which are easily identifiable by untrained personnel, such as, Spur-winged Plovers (Vanellus spinosus) and Stone Curlews (Burhinus oedicnemus), Chukars (Alectoris chukar), pigeons and doves (Table 1) as well as Cattle Egrets (Bubulcus ibis) and Hooded Crows (Corvus corone). White Storks (Ciconia ciconia) are also over estimated, one of the reasons being that pilots often report strikes with White Storks during migration, often without having feather remains collected.

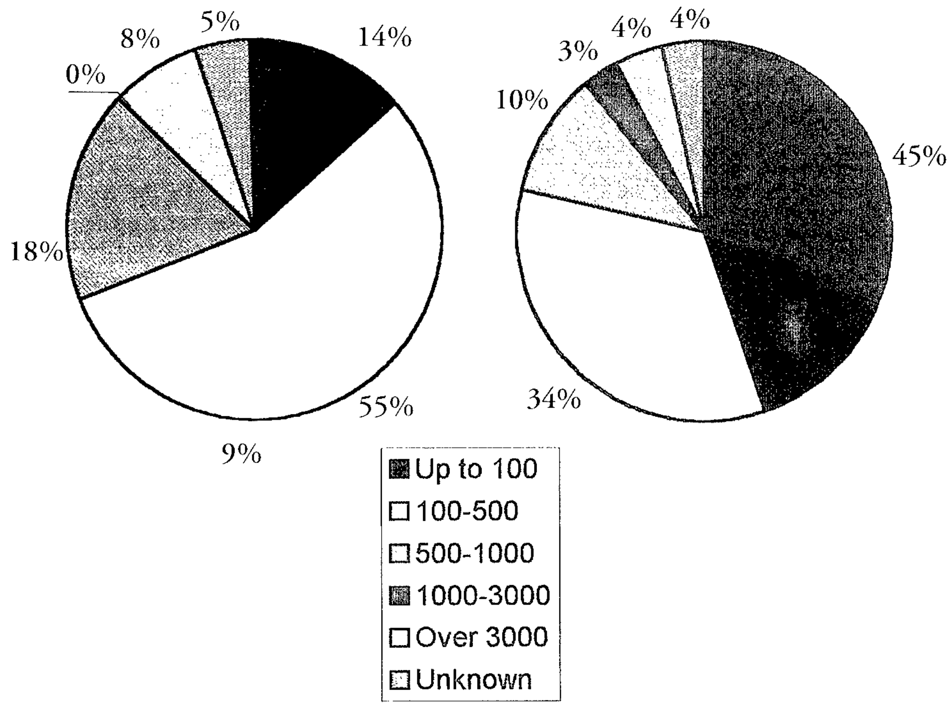
Table 1: Percentages of the most common birds involved in birdstrikes from 1991-1997 according to field identification compared to a combination of field and laboratory identification.

Species	**Percent of birdstrikes identified in the field (n=144)**	**Percent of birdstrikes identified in the field and/or laboratory (n=527)**
Stone Curlew (Burhinus oedicnemus)	11.1	9.1
Rock Dove (Columba livia)	16.0	7.4
Swift (Apus apus) and Alpine Swift (A. melba)	0.7	6.7
Chukar (Alectoris chukar)	11.8	5.1
Skylark (Alauda arvensis)	5.6	5.1
White Stork (Ciconia ciconia)	7.6	3.6
Spur-winged Plover (Vanellus spinosus)	6.91	3.2
Kestrel (Falco tinnunculus)	6.3	3.2
Hooded Crow (Corvus corone cornix)	6.3	2.5
Cattle Egret (Bubulcus ibis)	4.2	1.5
Black Headed Gull (Larus ridibundus)	2.8	1.3
House Sparrow (Passer domesticus)	2.8	0.9

Only 14% of the strikes involved birds weighing up to 100 g, according to field identifications, compared to 45% when both methods are combined (Figure 4). The proportion of smaller birds (weighing up to 100g) involved in birdstrikes are underestimated when only identified in the field, because minute feather remains cannot be identified in the field. The birds themselves are often harder to identify and probably harder to find on runway sweeps. Birds weighing 100-1000g are overestimated in the field. These mass classes include most of the common species found on bases.

Assuring the quality of feather identification is essential when using birdstrike statistics

Figure 4: *Mass classes (in grams) of birds identified by various methods 1991-1997: (A) in the field (n=144) and (B) in the laboratory and/or field (n=527)*



to develop bird hazard avoidance techniques. For this reason, identifications made by pilots and untrained staff should be used with caution if at all, and feather remains should be sent to someone trained in the field. Efforts are constantly being made to improve the level of bird-remains collection, identification, and reporting in order to receive sound statistics for further analysis and decision making.

BRIS is a unique, user-friendly system now commercially available, which provides both theoretical background information and a detailed database for identifying feather remains of birds from Europe and the Middle East. The system is particularly useful for people interested in entering the field but do not have access to reference collections of bird skins and/or funds for setting up a large database for microscopic feather structure comparison. BRIS does not eliminate the need for expertise in the field of feather identification, but is intended to be used as a tool to facilitate the learning process. This system can also be used for ecological studies of predator feeding habits, forensic work, and as an educational tool. This reference system is being expanded to include other techniques of identification as well as providing other sources of data important for bird hazard reduction (Prast et.al. 1998). Expansion of the BRIS to include new techniques and additional species depends on international cooperation and any parties interested in expanding the system are invited to contact the author.

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From a Local to a Regional Ground Survey Network and its Application in Flight Safety

Dan Alon, Judy Shamoun-Baranes and Barak Granit
Israel Ornithological Center, SPNI
Atidim Industrial Park, P.O.B. 58020
Tel Aviv 61580, Israel

Abstract

Israel is located at a bird migration bottleneck of international importance. Some two million soaring birds (storks, pelicans and birds of prey) are known to migrate over Israel twice a year during spring and autumn migration. These large numbers of birds pose a serious threat to flight safety. However, being such a "narrow" country facilitates stationing a network of grounds observers along the width of the country fairly easily, which, in turn, enables counting and positioning most of the birds as they migrate through the country.

Since 1977, the Society for the Protection of Nature has been leading the autumn soaring bird survey in Israel. As of 1984, this survey has been used as a tool to reduce collisions with military aircraft. From the start, the network has been proven to be an efficient tool in providing information in real time, particularly when combined with radar tracking.

In autumn birds migrating from Europe to Africa cross both Jordan and Israel. The possibility of extending the network in northern Israel eastwards through Jordan would benefit both countries.

Israel is well known as a bottleneck for migrating palearctic birds, particularly soaring birds, migrating from their breeding grounds in Eastern Europe and Western Asia to their wintering grounds in Africa and back (Alon et. al. 1992, Leshem and Yom-Tov 1996). Medium to large soaring birds avoid crossing large bodies of water such as the Mediterranean Sea during migration and hence utilize land bridges, such as Israel, to reach their destinations.

In autumn, the majority of soaring birds migrates through Israel along two major flyways, the western flyway, along the central mountain range, and the eastern flyway, along the Jordan Rift Valley (Leshem and Yom-Tov 1998). Unlike in the spring, the southern route through Eilat is almost inactive. The only species with significant numbers migrating along the southern route in autumn is the Steppe Eagle (Aquila nipalensis) (Shirihai and Christie 1992).

Autumn migration of soaring birds over Israel has been surveyed by ground observers systematically since 1977 (Dovrat 1991, Tsovel and Alon 1991, Leshem and Yom-Tov 1996). Israel's geographic location and the design of the Northern Valleys Autumn Migration Soaring Bird Survey provide a unique opportunity to conduct long term monitoring

of migrating populations of soaring birds, particularly Honey Buzzards (Pernis apivorus), Levant Sparrowhawks (Accipiter brevipes), Lesser Spotted Eagles (Aquila pomarina), and White Storks (Ciconia ciconia). In some cases, this data provides essential information on world populations, presently lacking, from their respective breeding regions.

The combination of large numbers of birds migrating across very limited airspace over a short period of time has created an acute flight safety problem in Israel. Since 1985, the Israel Air Force, in cooperation with the Society for the Protection of Nature, has been utilizing these soaring bird migration surveys to provide detailed information on bird migration for flight planning in relation to the bird migration hazard (Bird Plagued Zone Regulations) and for real time warnings to the Israel Air Force.

This paper summarizes the Northern Valleys Autumn Migration Soaring Bird Survey counts from 1990-1998.

Methods

From 1977 - 1987, the Kfar Kassem Survey was conducted over central Israel (Dovrat 1991). As of 1988, the annual autumn soaring bird migration survey is conducted across the northern valleys of Israel. The Israel Ornithological Center is responsible for both surveys.

The Northern Valleys Autumn Migration Soaring Bird Survey opens every year on 10 August with the beginning of the White Stork migration. Until 25 August, 3-4 stations are opened, from the Jordan border (61 km from the Mediterranean coast) to 54 km from the coast. From 25 August, honey buzzards start passing on a wider front. With this change in migration, the survey extends westward, up to 30 km from the coast, with 10-11 active stations. As the species composition during migration changes, the survey moves west. During the period of Lesser Spotted Eagle migration (25 September-15 October), the stations are run between 11-46 km from the coast.

Station Placement

The stations must be more or less in a straight line across the migration front and at a distance allowing identification of the majority of raptors crossing the front. For minimal coverage of a 35 km-wide migration front, at least 12 stations placed 3 km apart are positioned. Stations are numbered according to their distance from the Mediterranean coast.

All stations are opened approximately one hour after sunrise, as raptors start taking off, and close an hour before sunset, as diurnal migration stops. There is a bird watcher at each station equipped with binoculars, a telescope, and radio communications. Radio communications assist in informing the Israel Air Force about soaring bird migration as it occurs. The bird watchers complete observation forms recording the following information: hour, species, number, distance from station, estimated altitude, direction of migration. Double counts were eliminated after comparing daily counts for each station.

Summary Calculations

For each species, the average peak day of arrival was calculated by summing-up the total daily counts for all years and dividing by the number of years examined. The highest average daily count was considered the average peak day of arrival. Data from 1990-1998 was pooled for the birds of prey and from 1990-1995 and 1998 for the White Stork.

The range for the passage of 90% of the population of each species was calculated by summing-up the percent of daily counts and eliminating 5% of the total annual count from the beginning and end of the migration season (Table 2, Figs. 1-4).

Results

Between 1990-1998, 35 species of birds of prey (Accipiteriformes) were observed, on average, a seasonal total of 442,954 birds. In addition, two species of storks (Ciconia ciconia, C. nigra) and White Pelicans (Pelecanus onocrotalus) averaging a total of 274,943 birds were observed annually. The majority of the Palearctic population of Lesser Spotted Eagles, Levant Sparrowhawks, and White Pelicans, migrate over Israel. Table 1 provides the seasonal total for all species of soaring birds observed during the survey from 1990-1998. The four most abundant species are Honey Buzzards, White Storks, Lesser Spotted Eagles, and Levant Sparrowhawks, in that order. The peak year of migration for each species varies; in 1997 522,555 Honey Buzzards were counted, as well as 540,000 white storks, whereas 1990 was the peak year for Lesser Spotted Eagles with 83,701 birds counted and 60,390 Levant Sparrowhawks in 1994 (Table 1).

Table 2 shows summary statistics for the four main species, providing an overview on the timing of migration over the northern valleys in Israel. Each species shows its own distinctive migratory patterns, both in the timing of migration and their migratory route. The White Stork is the first species to appear in large numbers, the peak day of migration falls between 23 August and 7 September, the average peak day of arrival is 26 August (Fig. 1). The Honey Buzzards follow, with the peak day of migration falling between 1 September to 13 September, the average peak day is 4 September (Fig. 2). The Levant Sparrowhawk's peak day of migration falls between 20 September and 26 September, on average, 22 September (Fig. 3). The last of the main species is the Lesser Spotted Eagle with the peak day of arrival falling between 27 September through 5 October, 1 October being the average peak day (Fig. 4). The White Stork migratory season is the longest with 90% of the migrants passing during 23 days, followed by Honey Buzzards, Lesser Spotted Eagles and Levant Sparrowhawks with the shortest season, 90% of the migrants passing during 13 days (Table 2).

For several species, particularly the Honey Buzzards, there are large annual fluctuations in numbers. There may be several reasons for these fluctuations.

1.Migratory axis: During certain years, a large part of the migratory axis passes east of the survey, in Jordan. In such years numbers counted are low. This reflects an annual shift in the migratory axis.

2.Altitude of migration: The altitude at which birds pass over observation stations can effect the bird counts. During days when birds pass over at high altitudes, a certain proportion may not be counted by the observers.
3.Station position: The setup of the survey stations is based on historic knowledge of the migratory patterns of soaring birds. For example, on days when the axis shifts dramatically either east or west (usually the result of unusual weather) the survey misses many birds. On days with strong easterly winds, the entire axis of all soaring migrants shifts to the west.

Discussion

Large numbers of soaring birds are counted every year. However the averages do not always reflect the annual totals because of annual fluctuations in counts. For example, in 1995 221,669 Honey Buzzards were counted compared to 522,555 in 1997 (Table 1). Similar fluctuations were also seen in other species.
Each of the three major raptor species utilizes a slightly different migratory pathway within Israel. The later in the season the species arrives in Israel, the closer to the coast (the farther west) the species passes (see Leshem and Yom-Tov 1998 for explanation). The direction of migration in autumn is south-south west.
Both White Storks and Honey Buzzards pass over the northern part of Jordan as well as over Israel. Because the survey presently only reaches the border of Jordan, a significant proportion of these birds may not be counted annually. Cooperation with neighboring countries, particularly Jordan, by expanding the survey stations eastward, is essential for completing our biological knowledge of bird migration in the region and applying this knowledge for improving regional flight safety. In autumn, birds that cross northern Jordan will eventually migrate across southern Israel and can facilitate real time warnings to Israel and vise versa in the spring.
No major changes seem to have occurred in the population sizes of the Honey Buzzard and levant sparrowhawk since 1977 to the present, or with the White Stork population (from 1990) crossing Israel. However, though no change was seen in the Lesser Spotted Eagle population in this eight year review, a sharp and significant decrease in numbers is seen when comparing this survey to the Kfar Kassem survey. The authors feel that the sharp decrease in Lesser Spotted Eagle numbers is not related to the change in the survey positioning, but to a catastrophe that occurred in the breeding grounds that suddenly reduced the population.

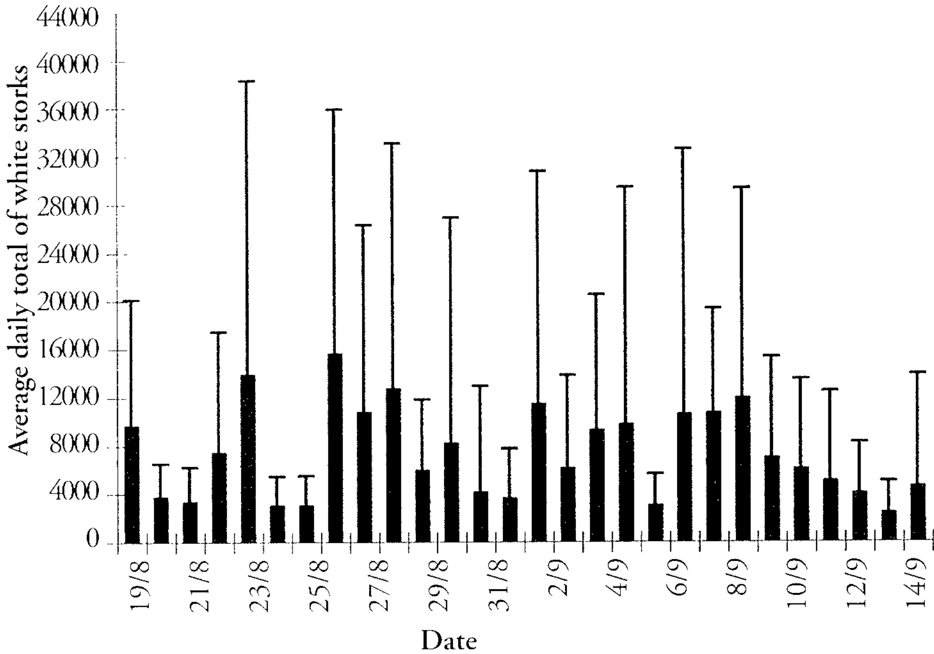

Figure 1. *White Stork average daily migration for 90% of the passing population from 1990-1995 and 1998 + standard deviations*

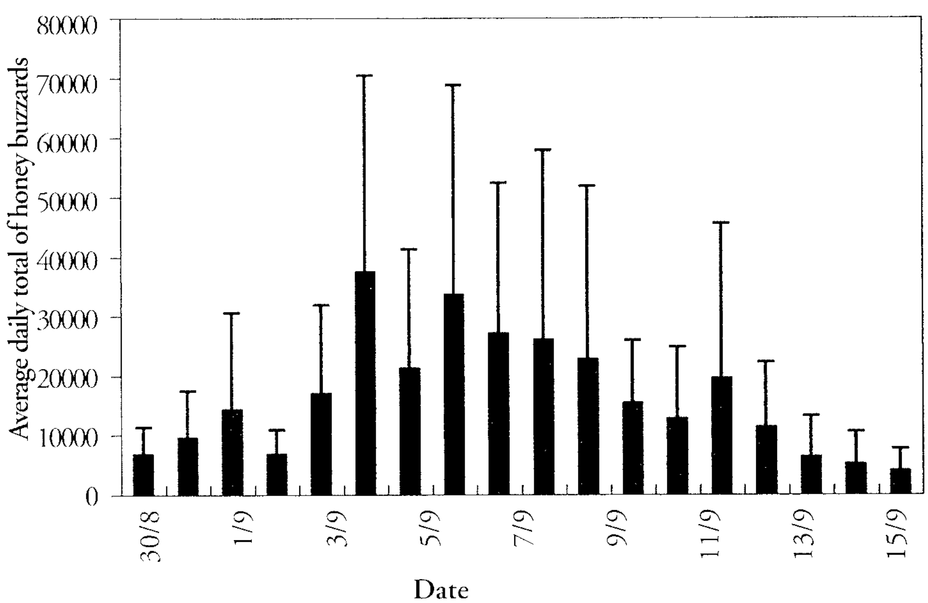

Figure 2. *Honey Buzzard average daily migration for 90% of the passing population from 1990-1998 + standard deviations*

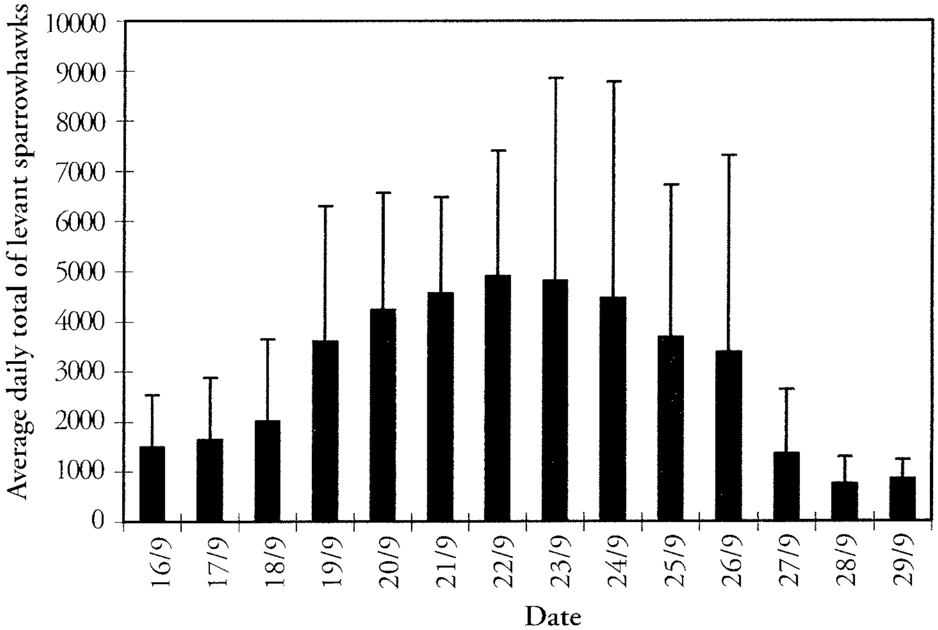

Figure 3. *Levant Sparrowhawk average daily migration for 90% of the passing population from 1990-1998 + standard deviations*

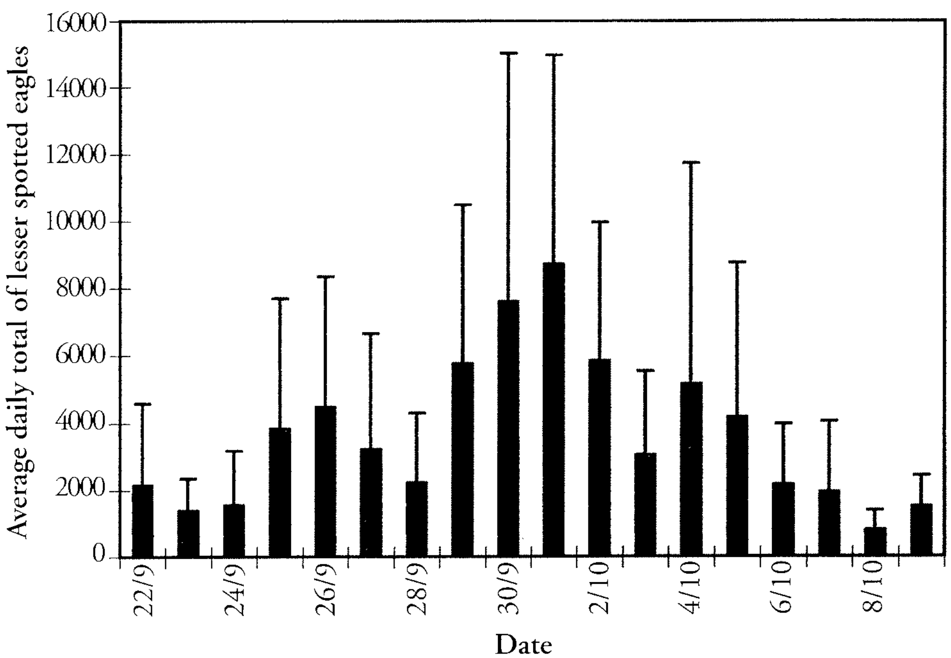

Figure 4. *Lesser Spotted Eagles average daily migration for 90% of the passing population from 1990-1998 + standard deviations*

Table 1. *Annual total of soaring birds counted during the Northern Valleys Survey from 1990-1998.*

Species Scientific name	Sum of 1990	Sum of 1991	Sum of 1992	Sum of 1993	Sum of 1994	Sum of 1995	Sum of 1996	Sum of 1997	Sum of 1998	Average
White Pelican Pelecanus onocrotalus	42575	30	45163	30239	30733	56765	25216	36470	37218	
White Stork Ciconia ciconia	188721	235906	173677	272975	293728	235084	278916	540000	165624	
Black Stork Ciconia nigra	2936	3299	1344	14100	7269	16898	7426	3617	7111	
Unidentified Storks Ciconia spp	150	7	120	0	0	0	0	40		
Osprey Pandion haliaetus	78	66	34	106	73	127	73	80		
White-tailed Eagle Haliaeetus albicilla	0	0	0	0	1	0	0	0		
Black Kite Milvus migrans	1734	2058	1369	2331	909	875	2695	1710		
Red Kite Milvus milvus	0	0	1	1	0	0	1	0		
Short-toed Eagle Circaetus gallicus	3819	4548	3325	3651	3288	3551	3024	3601		
Sparrowhawk Accipiter nisus	868	1131	884	797	358	408	155	657		
Levant Sparrowhawk Accipiter brevipes	41722	53704	37738	38667	60390	32878	56386	45228	52673	46598
Goshawk Accipiter gentilis	3	4	4	1	2	0	2	2		

Species Scientific name	Sum of 1990	Sum of 1991	Sum of 1992	Sum of 1993	Sum of 1994	Sum of 1995	Sum of 1996	Sum of 1997	Sum of 1998	Average
Steppe Buzzard Buteo buteo vulpinus	1953	3619	1793	1047	1608	1169			426	1659
Buzzard Buteo buteo buteo	3	5	0	11	1	0			0	3
Long-legged Buzzard Buteo rufinus 25	27	22	39	44	95				32	41
Honey Buzzard Pernis apivorus	437433	269289	228574	476565	260982	221669	260148	522555	286799	329335
Bonelli's Eagle Hieraeetus fasciatus8	9	1	0	5	3		4	4		
Booted Eagle Hieraeetus pennatus	811	1006	641	669	673	495			627	703
Golden Eagle Aquila chrysaetos	0	0	1	0	0	4			0	1
Imperial Eagle Aquila heliaca	3	22	6	25	14	1			2	10
Spotted Eagle Aquila clanga	30	62	48	52	30	62			23	44
Lesser spotted Eagle Aquila pomarina	83701	70295	58320	68009	77241	73980	55303	79012	67013	70319
Steppe Eagle Aquila nipalensis	214	187	181	267	123	83			47	157
Egyptian Vulture Neophron percnopterus	161	219	92	201	114	82			10	139

Species Scientific name	Sum of 1990	Sum of 1991	Sum of 1992	Sum of 1993	Sum of 1994	Sum of 1995	Sum of 1996	Sum of 1997	Sum of 1998	Average
Black Vulture Aegypius monachus	0	0	1	0	0	0			0	0
Griffon Vulture Gyps fulvus	62	25	43	83	37	45			40	48
Marsh Harrier Circus aeruginosus	1516	1550	719	1614	1517	1045			982	1278
Hen Harrier Circus cyaneus	9	6	4	0	6	2			0	4
Pallid Harrier Circus macrourus	26	47	28	37	129	28			30	46
Montagu's Harrier Circus pygargus	55	79	58	88	252	104			184	117
Saker Falcon Falco cherrug	0	0	1	0	0	2			0	0
Lanner Falcon Falco biarmicus	1	1	0	0	1	0			0	0
Peregrine Falco peregrinus	17	15	4	4	5	0			10	8
Eleonora's Falcon Falco eleonorae	15	12	4	18	7	0			3	8
Hobby Falco subbuteo	19	71	10	7	41	79			20	35
Merlin Falco columbarius	2	0	0	0	0	0			0	0

Species Scientific name	Sum of 1990	Sum of 1991	Sum of 1992	Sum of 1993	Sum of 1994	Sum of 1995	Sum of 1996	Sum of 1997	Sum of 1998	Average
Red-footed Falcon Falco vespertinus	4200	2392	2487	1613	445	252		9993	9633	3877
Lesser Kestrel Falco naumanni	9	26	9	4	20	5			34	15
Kestrel Falco tinnunculus	3	41	2	28	60	144			45	46
Unidentified raptor	2150	2905	885	755	1154	654			576	1297

Table 2. *Summary statistics for the four main species.*
For white storks, calculations are for 1990-1995 and 1998, for all other species, from 1990-1998.

Species	Average Seasonal Total	Peak Day of Arrival	Percent of population on peak day (range (average))	Number of day for 90% of population passage (range (average))
White stork	230 579	26 August	17-36 (26)	15-33 (23)
Honey buzzard	329 246	4 September	13-28 (19)	12-21 (17)
Levant sparrowhawk	46 595	22 September	11-26 (18)	10-16 (13)
Lesser spotted eagle	70 365	1 October	13-39 (22)	11-19 (15)

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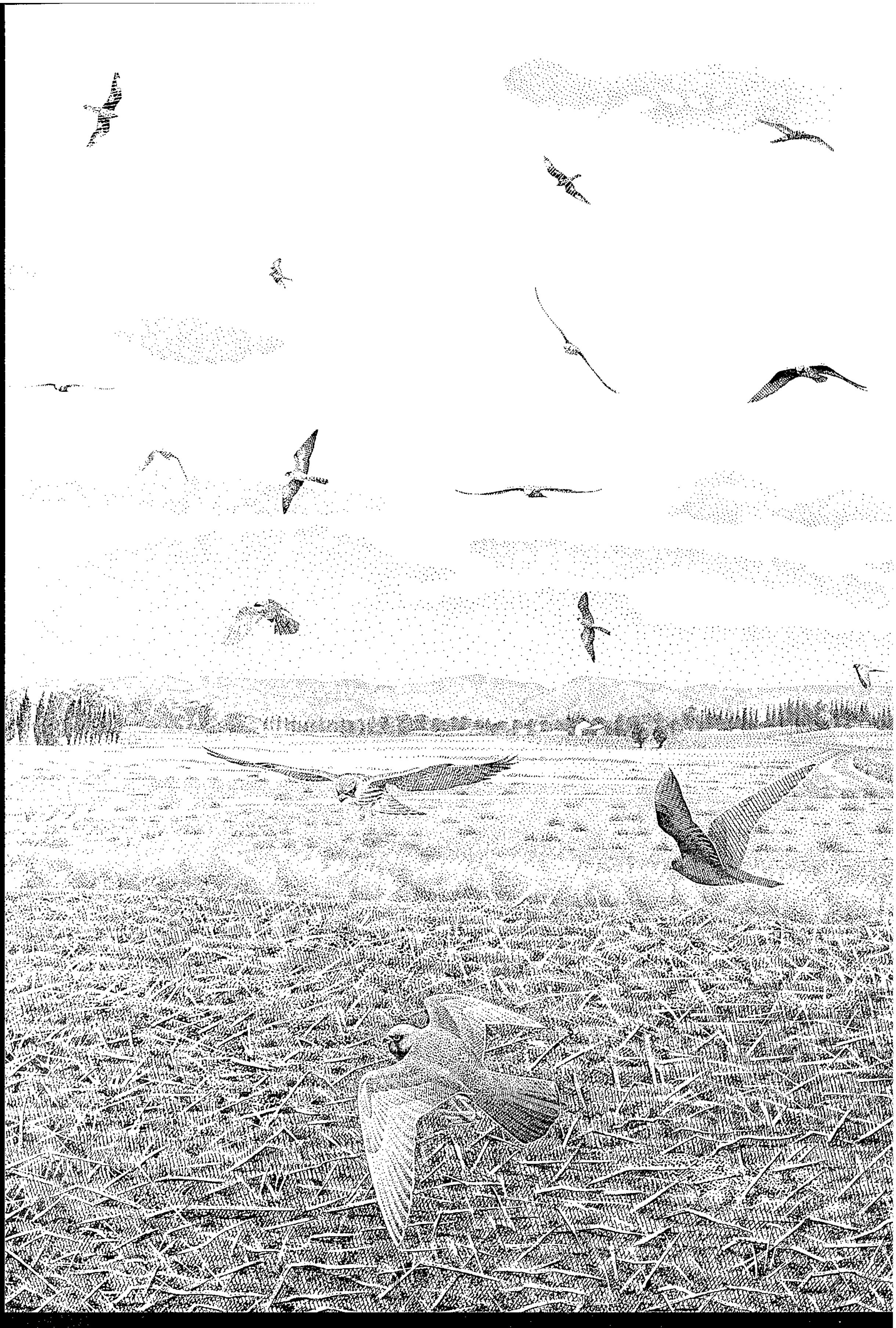


Twenty-eight Years of Birdstrike Damage In The Israeli Air Force (IAF) 1972-1999

Yossi Leshem[1], Yael Mandelik[1], Oded Ovadia[1], Judy Shamoun-Baranes[1], Eric Weismann[2]

[1]George S. Wise Faculty of Life Sciences, Department of Zoology, Tel Aviv University, Ramat Aviv, Tel Aviv 69978, Israel.

[2]Commanding Officer of Flight Safety Branch, Israel Air Force, P.O.B 02704, I.D.F. Israel.

Abstarct

Security regulations, the Israel Air Force (IAF) did not permit publication of birdstrike damage before 1994. Now that permission has been obtained, a summary of the number of bird-aircraft collisions in the IAF can be published. Data for 1972-1983, before the joint Tel-Aviv university, the Society for the Protection of Nature in Israel (SPNI) and IAF, research project started, is compared to data for 1984-1999, while research and implementation was going on. This paper presents data on birdstrikes in relation to month of the year and with emphasis on the heavy migration seasons characteristic to Israel. Birdstrike data of fighter aircraft is compared to that from helicopters, carriers and light aircraft. Finally, birstrike data before and after the research project began is compared. This comparison shows, that during the past decade damage has been reduced by 76% and the IAF has saved an average of 30 million dollars per year (450 million dollars).

Introduction

Despite its small size, Israel is strategically located at the junction of three continents. As a result, Israel is a "bottleneck", into which all or a large part of the world populations of certain soaring species converge, during spring and autumn.

Quantitative radar studies on bird migration done by Bruderer in two sites in the southern part of Israel (Bruderer 1992) brought him to the conclusion that not only diurnal soaring birds are funneled through the area of Israel, but also nocturnal migrants occur in higher densities than elsewhere. Calculating migration traffic rates and extrapolating them to the whole width of the area between the Mediterranean coast and the Jordan mountains showed that about half billion birds may cross the area in autumn.

Naturally, Israel's special location, unusually large migratory mass of birds, and limited air space generated strong conflict between migrating birds and aircraft. Until recently, the IAF would not release birdstrike data for security reasons. Now partial publication of the data is allowed. Therefore, this paper will deal with partial analysis of the data collected during 28 years of collisions with birds.

During the Six Day War, in June 1967, Sinai was occupied by Israel, and in April 1982, as part of the peace agreements with Egypt, Sinai was returned to Egypt. During 1967-1982 Sinai was used as a central training area for IAF aircraft, mainly because of its large area (approximately three times bigger than of the state of Israel). With the withdrawal from Sinai, and the considerable increase in the number of IAF aircraft, a serious problem of limited airspace was created, within which training had to occur, resulting in many collisions with birds, especially during migration. The IAF initiated a joint research program with Tel-Aviv University and the Society for the Protection of Nature in Israel (SPNI) which started in 1984, the goal of which was to significantly decrease the risk of birdstrikes during migration.

Methods

Until 1983 data on military aircraft collisions was collected manually and from 1983 onward, data was computerized and held in a data bank in the flight safety department of the IAF. The data presented here was taken from the IAF data bank. In addition, further data was collected from personal interviews with control units, IAF pilots and the birdstrike prevention crew.

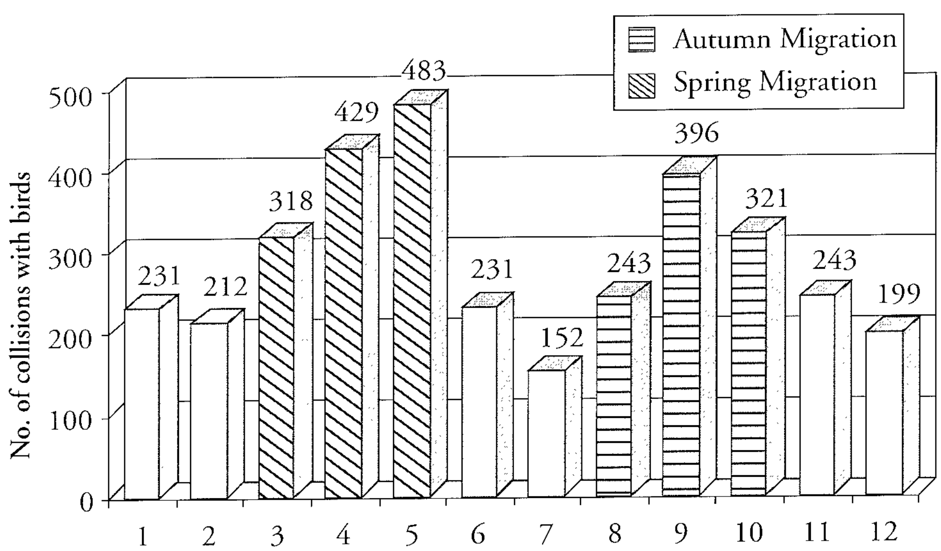


Figure 1: *Total number of bird-aircraft collision in relation to the months of the year, 1972-1999 (n=3458)*

From the data it is apparent, when analyzing birdstrikes during several years, that the six months of migration, March, April, May (spring migration), September, October and November (autumn migration), are the months during which most birdstrikes occur (fig. 1). Out of 3458 birdstrikes, during 28 years, approximately 123 birdstrikes were recorded annually in the IAF. The multi-annual average of birdstrikes for each migratory month is 10.5% of all annual collisions, whereas during the six non-migratory months, 6.1% of the total number of annual collisions occur each month. From this it is apparent

that during the months of migration the number of birdstrikes increases 63%. Analysis of birdstrikes with IAF aircraft according to type of plane (fig. 2) was divided into three main categories: fighter planes, helicopters, and transport and light aircraft. From the data in figure 2, it is obvious that fighter planes are involved in almost twice as many birdstrikes as the other categories (43% fighter planes, 29.6% helicopters, 26.1% transport and light aircraft).

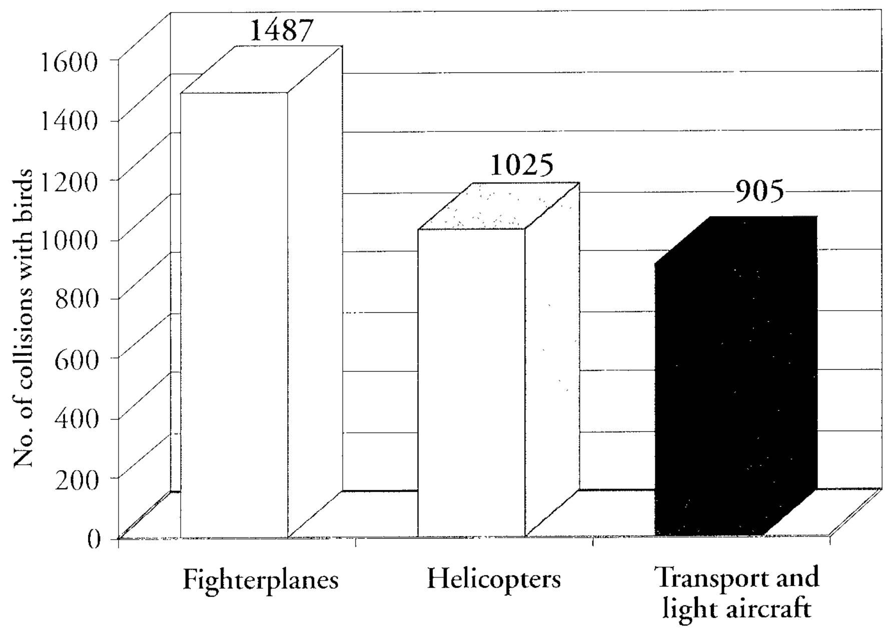


Figure 2: *Total number of bird-aircraft collision in the Israel Air Force in relation to aircraft types 1972-1999*

Table 1 shows the analysis of serious damage done to fighter planes (damage level 3-5) during 1972-1983. During this time there was an annual average of 3.18 serious birdstrikes, including the destruction of five fighter planes! On October 28, 1974, at the height of pelican migration, fighter pilot Major Sephi Levin led a Skyhawk formation at low altitude in the Hula Valley in northern Israel. At 12:56 a pelican collided with his plane, penetrated the aircraft's canopy, and killed the pilot.

Table 1: *Total serious collisions with fighter aircraft in the Israel Air Force, 1972-1983.*

Type of aircrat damaged	Mirage	F-15	Phantom	Kfir	Skyhawk	Total
Level 3 (over $100,000)	1	2	4	4	15	26
Level 4 (over $500,000)	-	1	-	1	2	4
Level 5 (aircraft destroyed)	1	-	-	1	3	5
Total	2	3	4	6	20	35

Collisions at bases: 4
Collisions in open areas: 31 (88%)
74% of the serious collisions occurred during migration

During 1984-1989, in the joint study conducted by the SPNI, the Ministry of Science and Technology, and the Tel Aviv University (Leshem 1990, 1992), the following parameters were defined: specific migration routes of raptors, storks and pelicans, the altitude of migration, time of arrival of migrating raptors, storks and pelicans the peaks for each species, and how the whole system is effected by changes in climate.
During the study, in 1984, the IAF adopted the B.P.Z. (Bird Plagued Zone) policy and stopped flying within the migratory paths at the altitudes, hours and seasons defined in the study. Throughout the study errors were corrected and as a result, there was a decrease of 76% in collisions between migrating birds and fighter planes. The calculations of financial savings during this time, based on the fact that most of the IAF fighter planes are F-15's and F-16's costing up to 45 and 27 million dollars respectively, reaches 30 million dollars annually, and during the last decade since the beginning of the joint study financial savings reached 450 million dollars.
It is important to emphasize that the birdstrike data from 1972-1983 is from the period when most of the IAF training was in Sinai. There is no doubt that without the B.P.Z. the amount of damage would have increased significantly when the IAF fighter planes division increased and simultaneously had to train in limited airspace after Sinai was returned. Figure 3 shows the relative decrease in damage after the B.P.Z. was initiated, though the exact numbers are still classified.

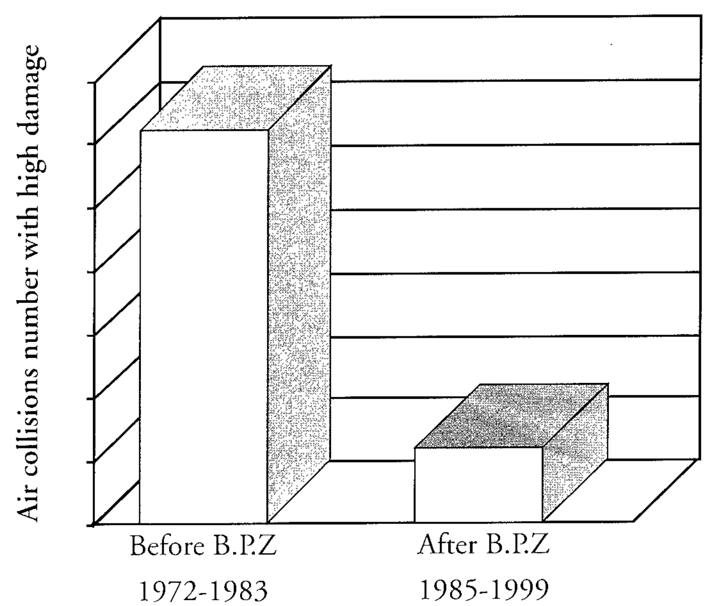
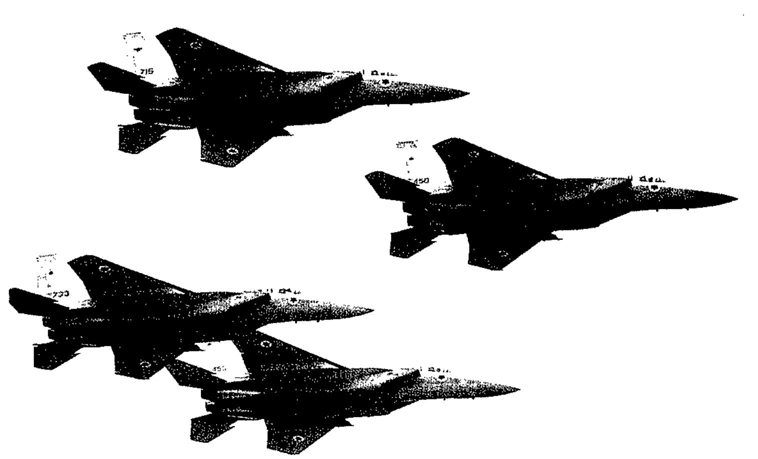
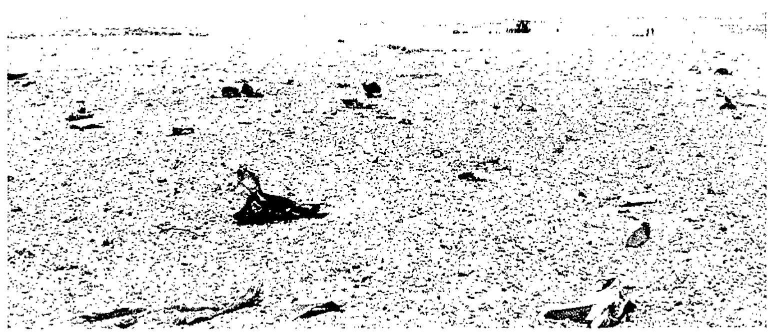


Figure 3: *Averagre yearly fighter aircraft before and after regulations of Bird Plagued Zones (B.P.Z) damaged (level 3-5) during migration months*

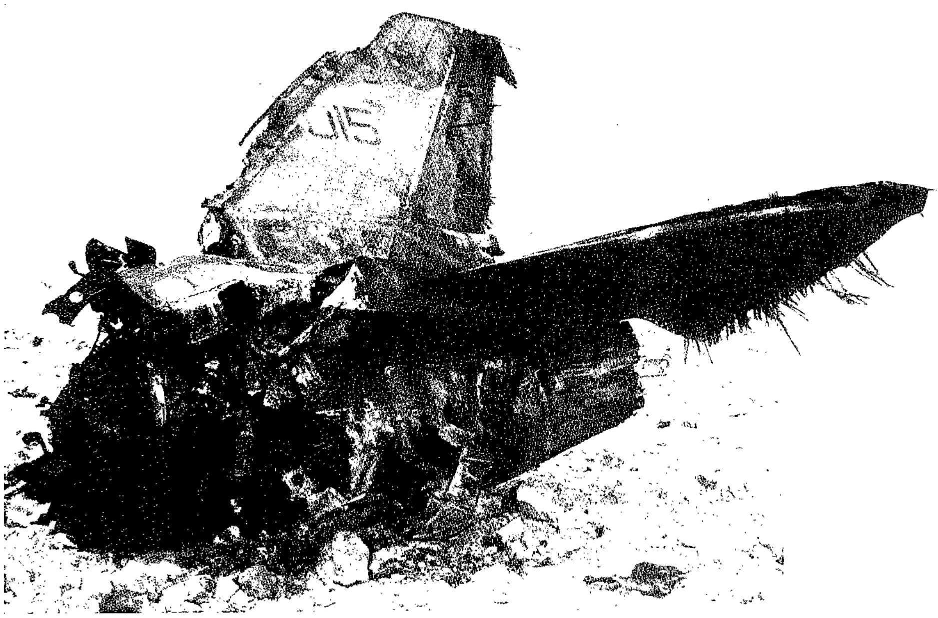


Two months before the fatal accident, the pilot, Captain Ronen Lev, and the navigator, Captain Yaron Vivente flew their F-15 planes during the celebrations of Israel's Independence Day



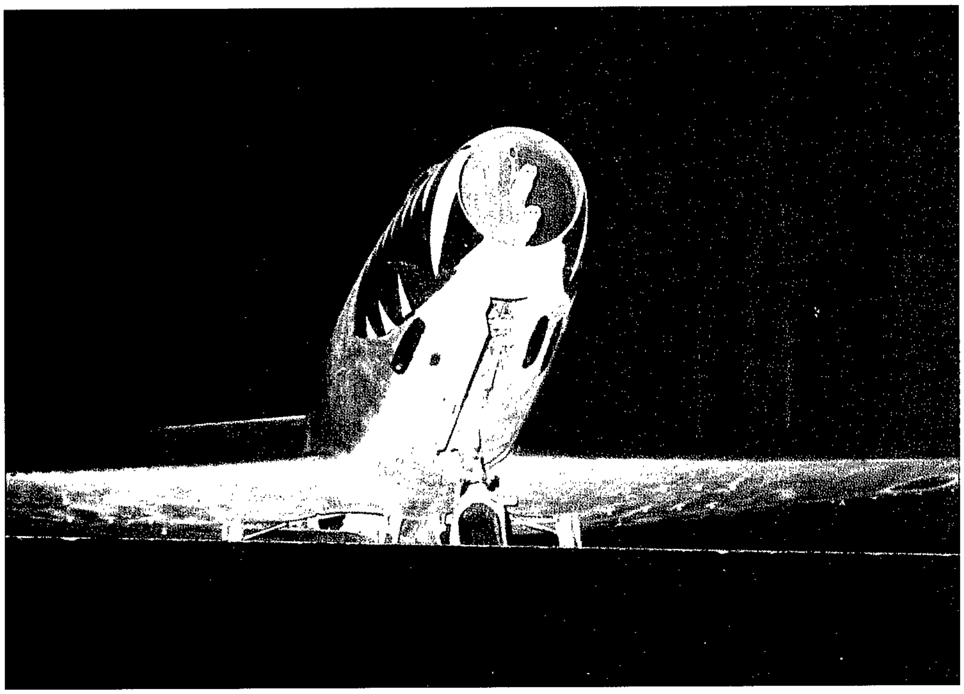
Remains of the F-15 scattered in an area of 400X400 meters in Nahal Zin.

Remains of the two storks that collided with the F-15 (photos: Rubi Kastro)



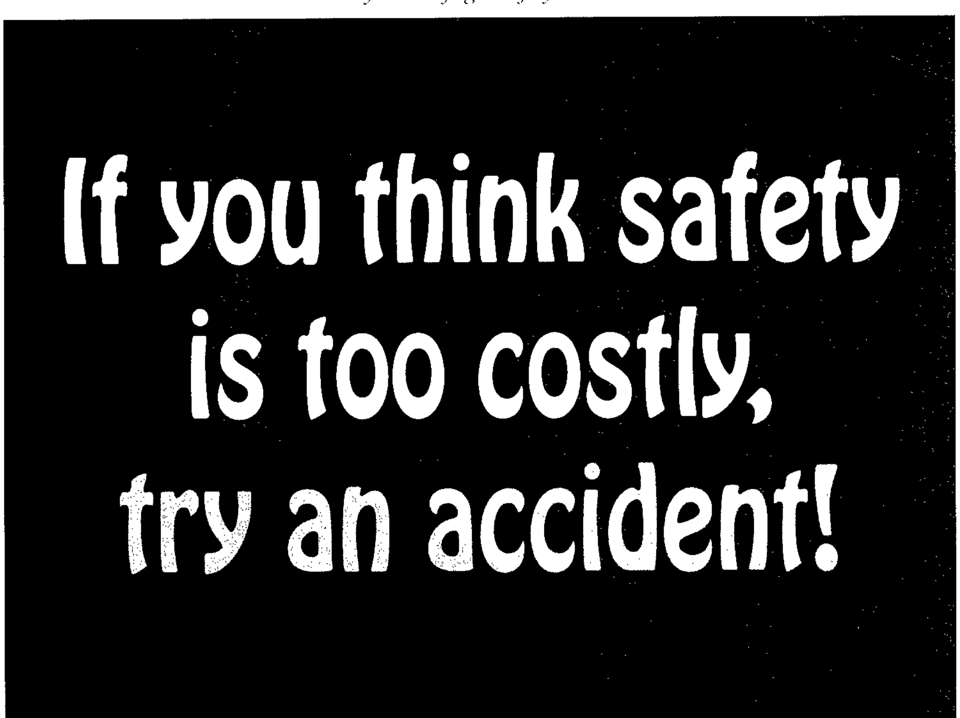
Above: *Remains of an F-16 tail hit by a Golden Eagle over the Judean Desert in December 1988 (Photo courtesy of the IAF)*

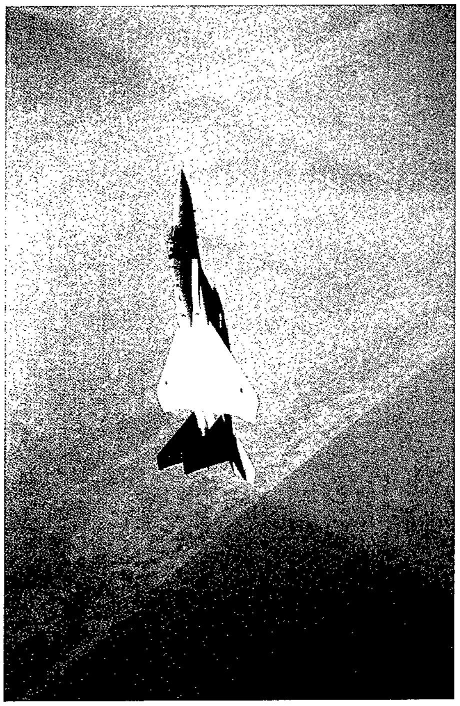
Below: *The research motorized glider soaring with 2000 migrating White Pelicans over Israel (Photo: Gery Young)*



Above: *A pair of Barn-Owls nesting in the IAF Airbase in the Super-Mister decoration.*

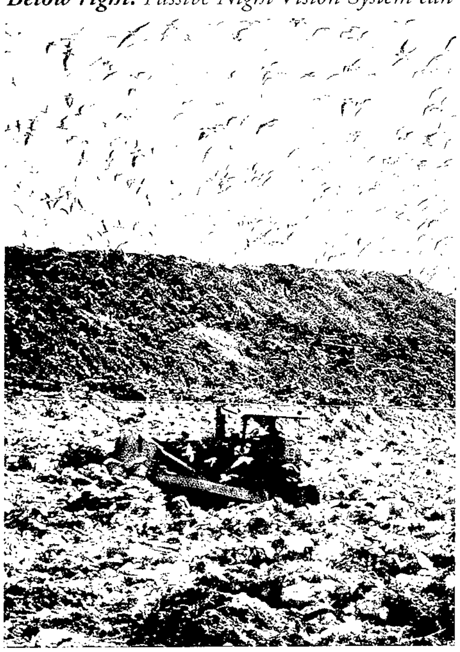
Below: *What the "wise owl" has to say about flight safety!!*

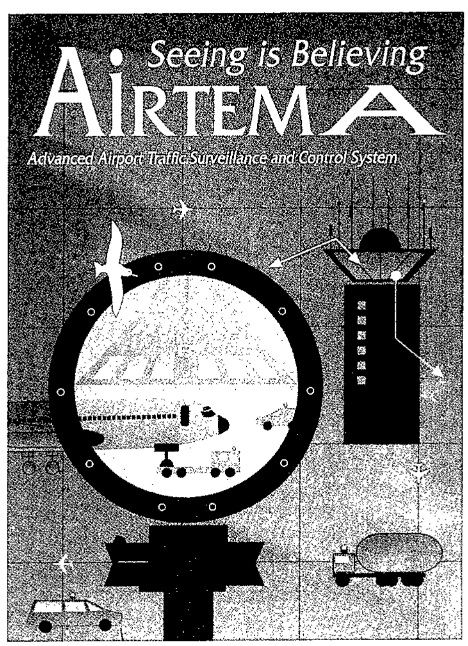




Above left: *An F-15 manouvers along the coast line of the Mediterranean (Courtesy: IAF).* ***Above right:*** *A poster with a calendar indicating the BPZ dates forbidden to fly low.*

Below left: *The huge garbage-dump, Hiriya, which was a great threat to Ben-Gurion International Airport because of 100,000 wintering Gulls was closed in August 1998 (Photo: Yossi Leshem).* ***Below right:*** *Passive Night Vision System can help to avoid collisions at air bases.*





The research lasted almost five years (1984-1989) but already at the end of the first year the IAF published regulations and recommendations specifically for fighter planes. The main idea behind the regulations was to separate migrating birds from aircraft in both time and space. From the data in figure 4 it is very clear that right after this research began to receive great attention in the air force and the regulations were put into effect by the IAF in 1984, the number of bird-aircraft air collisions with damage decreased sharply from more than one hundred a year to less than thirty. The main regulations were to abstain from flight under 3000 feet during migrating seasons, especially within the migrating routes that were mapped in this research.

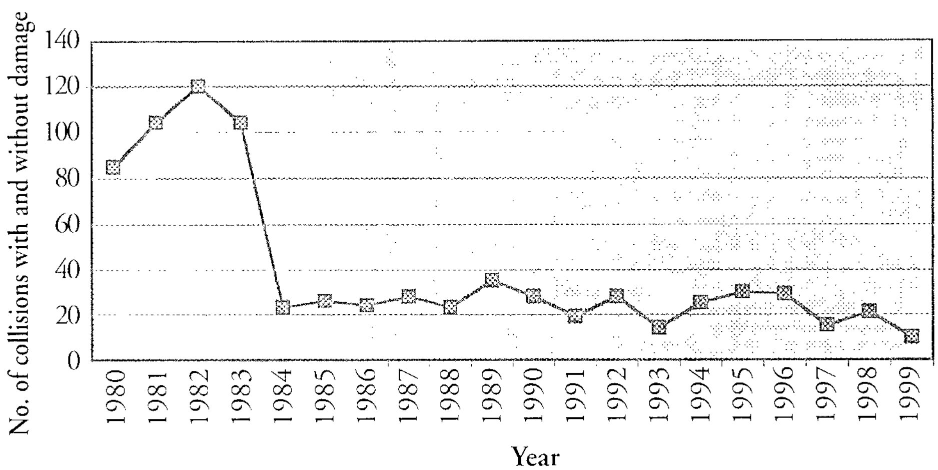


Figure 4: *The number of air collisions with damage from 1980 to 1999*

Until 1983 there was no systematic follow-up on the number of air collisions in the air force. After the regulations were published and pilots had become aware of the danger from migrating birds, more and more reports about air collisions were collected. In figure 5 we can see that from 1983 until 1989 the number of reports about air collisions increased. This is probably not because more collisions occurred in these years but because it took almost five years of intensive propaganda to increase the reporting levels of air collisions. Greater awareness and a high percentage of reporting are crucial to efficiently deal with the problem, because we know that the difference between air collision and severe accident is mostly luck!

From 1984 until the present there was no additional decline in the number of air collisions with damage. The high number of more than 200 air collisions per year has also remained stable from 1989 until the present.

In the beginning of the nineties, a new research project on feather remains identification was started as the M.S. thesis of Judy Shamoun-Baranes. With the completion of the research, we developed a campaign, directed particularly at ground crews, for collecting feather remains from planes after an air collision. Feather remains identification is also

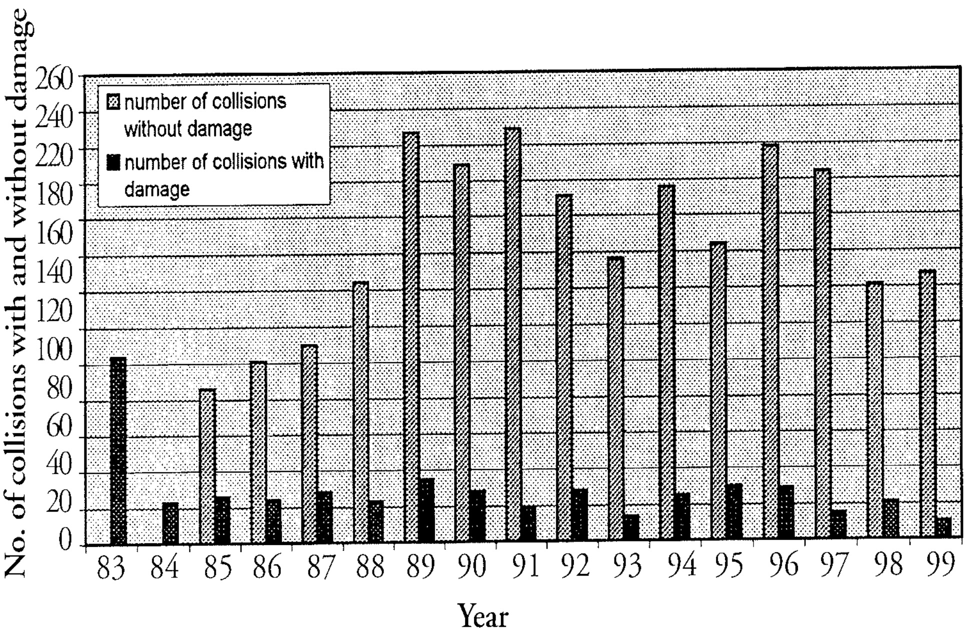


Figure 5: *The number of air collisions with and without damage from 1983 to 1999*

very important because we must study in detail what species of birds was involved in the collision, as well as when the collision occurred and what kind of damage was caused to the IAF aircraft involved.

In the beginning, remains from only 10-20% of the collisions were collected. From 1994 to 1996 (when the campaign ended), remains from 40-45% of the collisions had been

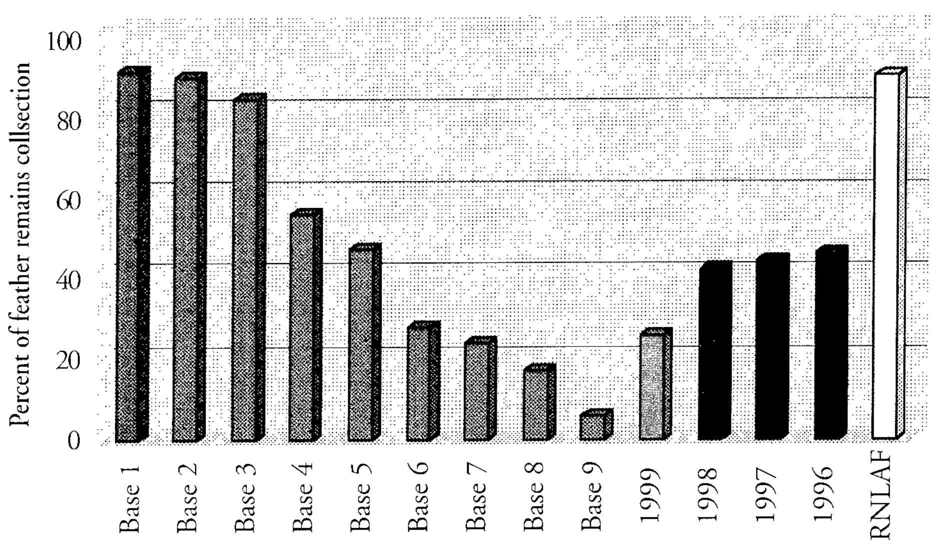


Figure 6: *Comparison of feather remains collection between different IAF bases in 1998 and annual IAF feather remains collection effort 1996-1999*

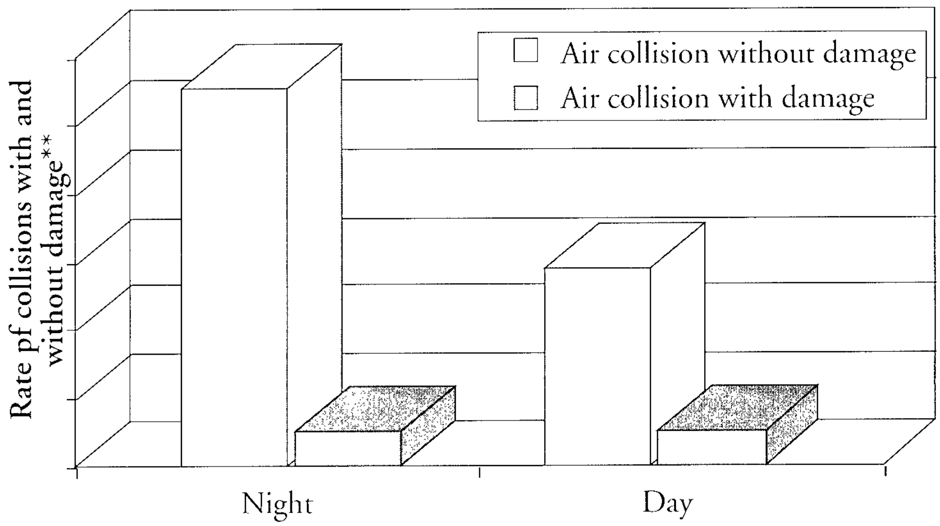


Figure 7: *Rate of air collisions with and without damage, in day flights and night flights from 1983 to 1995 (** the scale is missing because of security reasons).*

identified and from 1997-1999 it dropped down again up to only 24% of remains identification in 1999 (figure 6, black columns). In this figure we can also see that in the RNAF the perennial remains identification is 88%! Information is not only difficult to obtain, it is also clear from figure 6 (grey columns) that great variance was recorded among the reports from different IAF airbases. Variance in feather remains identification is due to the level of awareness and the effort that each base invests in this issue. Both can be changed significantly by an awareness campaigns.

As was mentioned in the introduction, the number of nocturnal migrating birds in this area is also very high. By comparing between day and night collisions, we found that the number of air collisions relative to the number of flight hours is almost twice for night flights compared with day flights, although the number of collisions in night flights is lower than in day flights. Because the birds that migrate at night are small and because there are less fighter planes flying at low altitudes and high speed at night, the rate of air collisions with damage is equal for night and day filghts.
day filghts.

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The United States Bird Avoidance Model (BAM)

Russell P. Defusco
Department of Biology, United States Air Force Academy
Colorado 80840, USA

Abstract

Thirty years of bird distribution and population data were collated with remotely sensed and ground-sampled environmental data to help predict occurrence of bird concentrations potentially hazardous to military aircraft. Data on numerous bird species considered most hazardous to military operations were derived from over 4,000 survey sites and correlated with environmental data from a variety of sources in a raster-based GIS system. Environmental data includes climatic, geographic, and physiographic factors sampled from meteorological monitoring stations, USGS topographic data, and AVHRR satellite imagery all spatially registered on a one kilometere grid system. Each square kilometer of the entire continental United States is designated with a bird risk value based on the cumulative biomass of birds in the area. A diverse variety of other data sets such as designated airspace, jurisdictional boundaries, infrastructure, and others are also included in the model. Interpolated risk surfaces were created to predict bird distributions and abundance for the entire continental US. These surfaces may be overlaid on any other data set in the model for sophisticated analyses. The computer interface for the users is a simple, personal computer-based, menu-driven program available on commercial software and over the Internet. Risk surfaces in map formats enable flight planners and aircrews to choose flight routes that minimize potential bird strikes to their aircraft.

Each year the United States Air Force (USAF) reports approximately 3,000 bird strikes to its aircraft. These incidents cost nearly $50 million on average. In the last decade, the Air Force has suffered the loss of 14 aircraft and 33 aircrew fatalities. The other US Department of Defense services report higher rates of strikes per flying hour and suffer similar losses. Civilian aircraft are not immune to this problem, and US airlines report nearly $100 million in annual losses. Most bird strikes occur around airfields where habitat management, bird dispersal techniques, and active population control can be employed. For military aircraft however, the majority of catastrophic incidents occur on high-speed, low-level, and range missions where bird control is not possible. The only alternative in these environments is to avoid known bird concentrations. This is where the Bird Avoidance Model (BAM) comes into play.

The BAM is a Geographic Information System (GIS)-based program using commercial software that integrates historical information on bird distributions and abundances with

various geographic and environmental factors. It creates graphic risk surfaces for determining the relative degree of hazard for any location in the Continental US. Data on bird populations and movement patterns comes from numerous government and private sources and is the result of literally millions of hours of field work from biologists, refuge managers, amateur bird watchers, and volunteers. Thirty years of data from over ten thousand locations throughout the country are evaluated and used as the basis for the model. Standard inverse distance weighted interpolation algorithms fill in the gaps between the surveyed locations so that each square kilometer of the US has a unique risk value assigned. Total coverage of the US BAM is 7.7 million square kilometers.

The initial version of the model includes over 60 species considered most hazardous to flight operations. Large birds such as waterfowl and raptors, and flocking species such as blackbirds and gulls constitute the greatest threat. A risk surface is generated using the available data and normalized by body weight for each species. The individual risk surfaces are then cumulatively added and a total risk calculated. Risk is based on the total biomass of birds in a given volume of airspace. Data are available for each two-week interval of the year and for various daily time periods. A color-coded graphic display, in a GIS map format is available for each data layer. Risk is portrayed as green, yellow, and red shades over the map surfaces corresponding with low, moderate, and severe bird hazards respectively. The scale of coverage can be selected by the user.

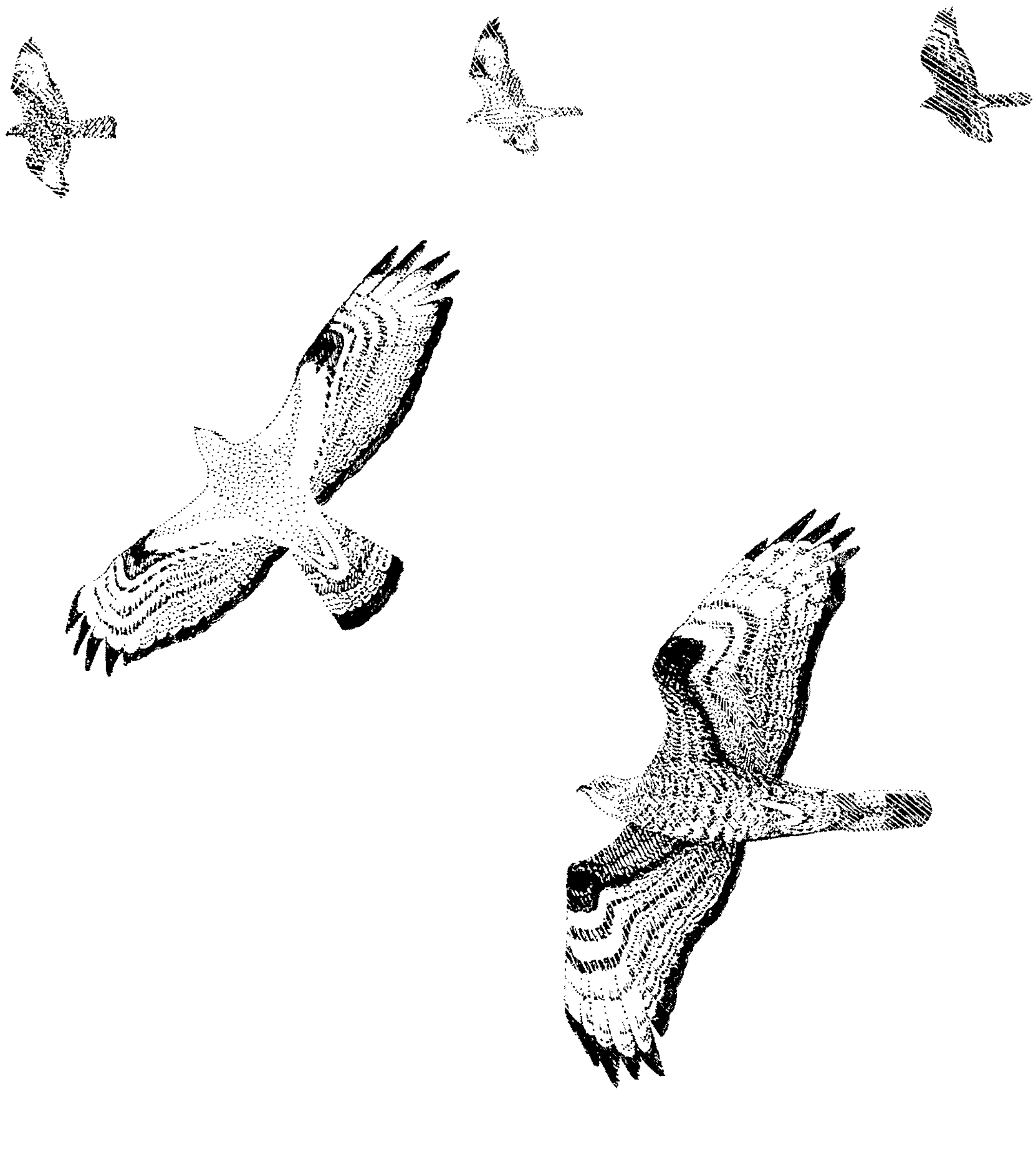
The user interface for the new BAM is a simple, menu-driven, PC-based program that allows flight planners, route designers, aircrew, and environmental planners to select the geographic location, time of year, and time of day that they desire to fly a particular route. Relative risks for each operation can be assessed by comparing routes to each other or by comparing various temporal alternatives on individual routes. Safest times and locations can then be selected by the user. The model also has numerous geographic and environmental data sets that can be overlaid on the bird risk surface. For example, the user can zoom in on a portion of the country, display the bird risk, and overlay roads, airports, aircraft operating areas, terrain maps, land uses, or a variety of climatic information such as temperature or precipitation on the computer display.

The model has been distributed by the Air Force Bird Aircraft Strike Hazard (BASH) Team to various users throughout the country. While the program and data needed to generate the Bird Avoidance Model require enormous amounts of computer space, the products of the model are available over the internet or alternatively on CD for the ultimate users. Full interactive capability will be available through each avenue of access. Anyone with internet capability will be able to access the model through various venues in the near future. There is also a much more sophisticated version of the BAM available for research and development purposes or for those select users requiring more detailed analysis capabilities and breakdown of constituent data sets.

The new BAM will provide a tremendous planning tool for the aviation community to reduce the incidence of bird strikes to aircraft. Organizations employing early versions

of the model have reported reductions in their bird strike rates of as much as 70%. The new model provides much more data and at a resolution orders of magnitude better than the previously existing models.

Our work is not done however. We need to field test the model, refine some of the data layers, expand to areas outside the US, and ultimately provide near-real time updates to the model using technologies such as doppler radars and satellite telemetry. A current collaboration is underway to extend this technique to countries in Europe and the Middle East. The Department of Biology at the United States Air Force Academy, in collaboration with the USAF BASH Team and other departments and agencies, will lead the effort to develop and refine the BAM in the future as long as sponsoring agencies continue their support of these efforts. Ultimately, we hope to make the skies a bit safer for those who share them with the birds.



Development of a GIS-based Bird Model Migration Model for the Middle East

Judy Shamoun-Baranes
Department of Zoology, Tel Aviv University, Tel Aviv 69978

Abstract

A regional model of bird movement is being developed at the International Center for the Study of Bird Migration at Latrun, in cooperation with the Society for the Protection of Nature and Tel Aviv University with the aid of EMC2, the Enterprise Storage Company.

ESRI (Environmental Systems Research Institute) Geographic Information System (GIS) tools are being used for data integration, analysis and geospatial display of historic bird migration data, environmental and landuse data, and near real-time migration data, to create a dynamic model of soaring bird migration in the Middle East. Presently, satellite telemetry data from 48 White Storks have been integrated into the system and seven storks with active transmitters are interactively linked to the system. In the future, telemetry data for other soaring birds will be added. Other data sources included in the model are motorized glider flights tracking Lesser Spotted Eagle, White Stork, Pelican, and Honey Buzzard migration routes and altitudes through Israel and the ground survey network, including the timing and intensity of autumn soaring bird migration across Israel. The information system is also linked to several meteorological datasets. One of the main objectives of the model is to study the relation between changing weather conditions, topography and the spatial distribution, timing and intensity of soaring bird migration. Preliminary results have already shown that a combination of several meteorological variables at the 850mb level, have a significant effect on the daily speed of migration.

The model is being designed in such a way that it can be expanded to include data from other countries and linked in the future to similar systems being developed around the world.

Introduction

Israel is an important bottleneck for bird migrating from Europe and Asia to Africa in the autumn and back in the spring. This is particularly true for soaring birds that avoid crossing large bodies of water such as the Mediterranean Sea because of their dependence on thermals.

The timing, routes and altitudes of migration of soaring birds over Israel has been studied in detail by Leshem and Yom-Tov (1996a, 1996b & 1998) using mainly ground surveys, motorized glider flights, and radar tracking . These aspects of migration were found

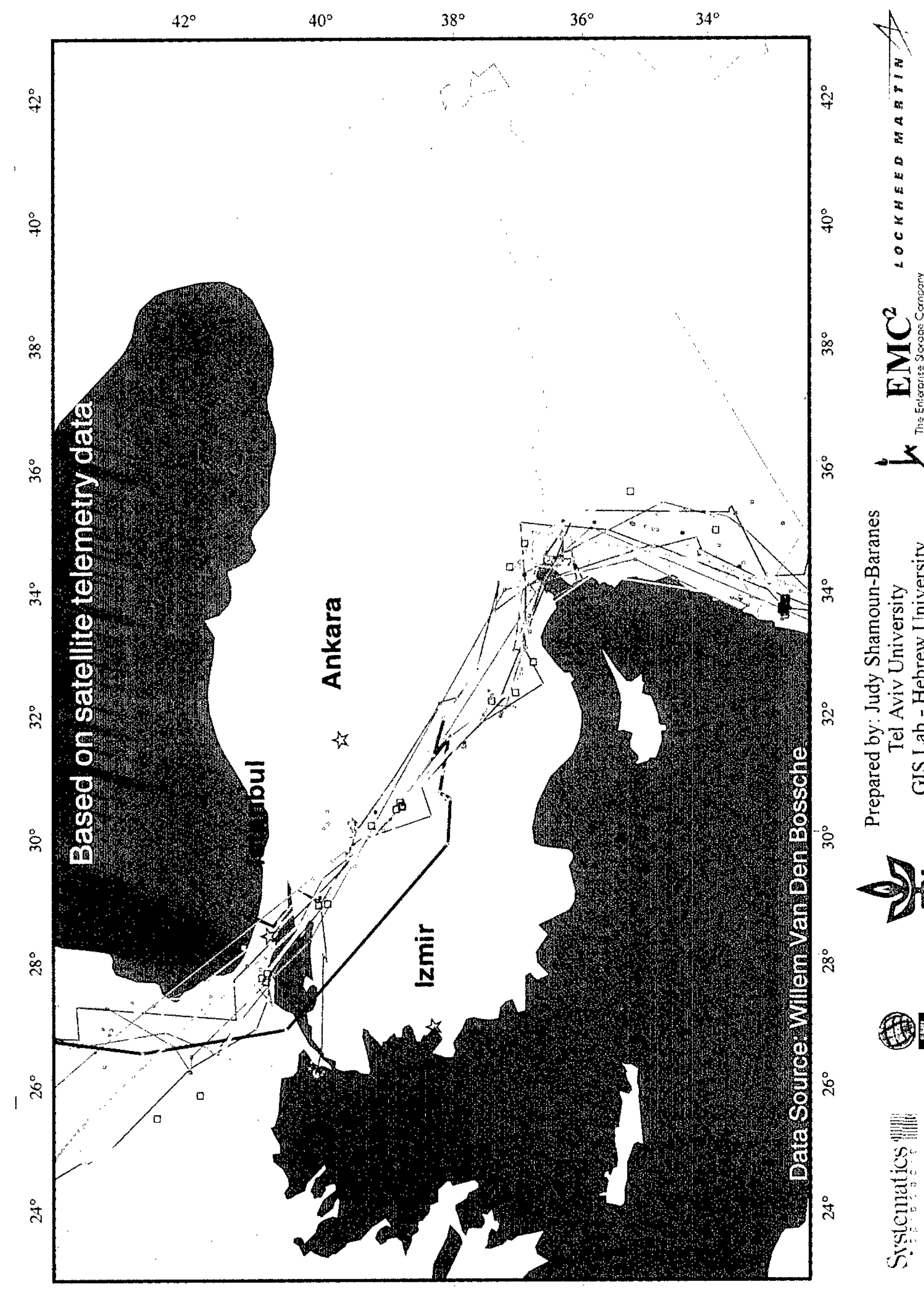
to be fairly predictable. In recent years, knowledge of individual migrants, their migratory route from nesting site to wintering sites, their stop-over sites, how long they spend in each area and how far they travel each day, has been collected using satellite telemetry (Berthold et. al. 1997, Meyburg et. al. 1995). This technology has given new insight into the migratory behavior of certain species.

Though many species of birds show rather consistent temporal and spatial patterns of migration, these patterns are flexible. Weather is assumed to play an important role in affecting migratory behavior. Factors such as passage of cold fronts, barometric pressure, wind direction and intensity have been shown to affect the flight behavior of soaring migrants (Allen et. al. 1996, Liechti et. al. 1996 and Maransky et. al. 1997). However, these studies generally focused on localized events and the effects of meteorological variables on the timing and intensity of soaring bird migration, particularly on a regional scale have not yet been elucidated.

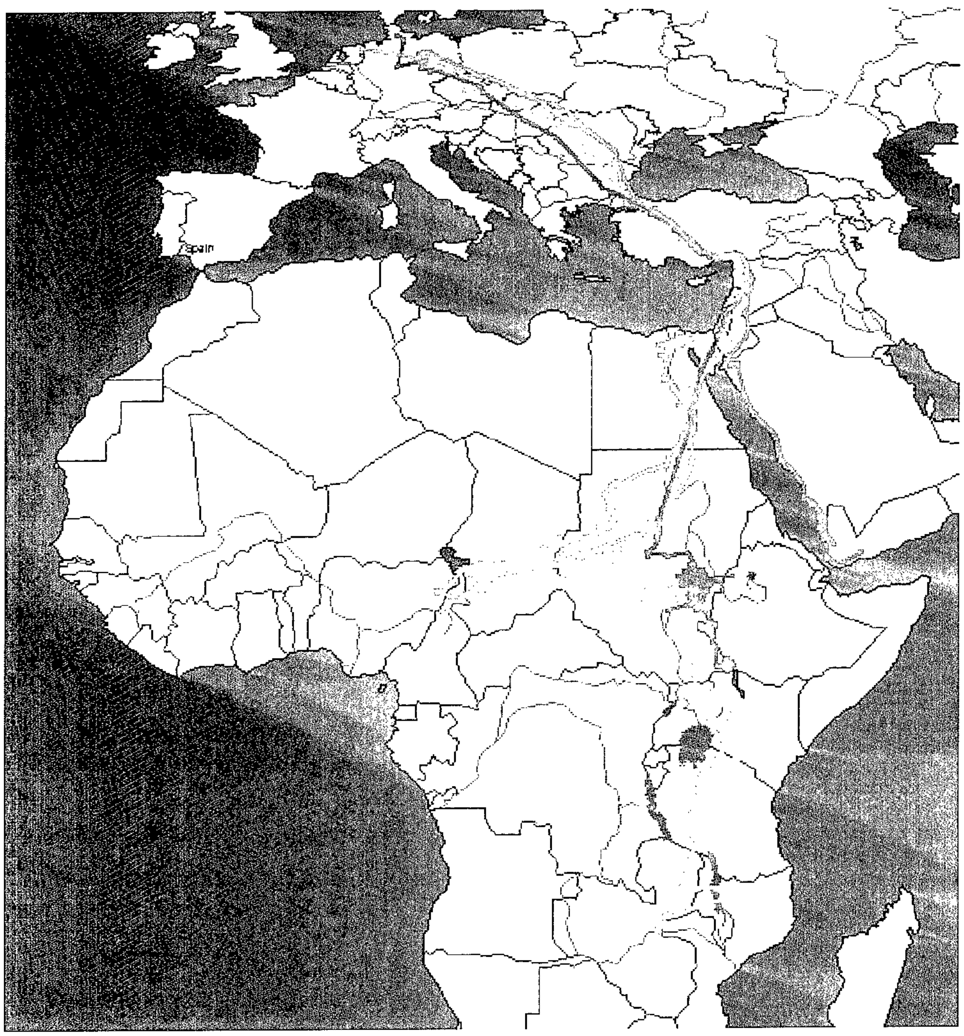
Birds have posed a serious threat to flight safety since the beginning of aviation. In recent years, damage to aircraft, particularly military aircraft, as the result of birdstrikes has increased significantly due to faster and lower flying aircraft, costing hundreds of millions of dollars annually and the loss of lives. The Israel Air Force (IAF) has also suffered severe losses to birdstrikes. Seventy four percent of the serious damage to IAF aircraft was from migrating birds. The data obtained from Leshem and Yom-Tov's study of bird migration over Israel (1996a, 1996b, 1998) was used to develop the "Bird Plagued Zone" regulations and a warning system for the IAF, which has reduced collisions with migrating birds in the IAF by 88% (Leshem 1994). However, the disadvantage of this system is that it is generalized in both time and space and limits flight training for seven months of the year.

In an effort to improve flight safety during the migratory months, the IAF has recently begun the process of creating a network of weather and bird radars throughout Israel in order to develop a real time warning system for the whole country. An integral part of this system, should be an historically based model of bird migration to provide the necessary biological data not only for a real time warning system but as a tool to improve flight planning.

This research project will attempt to develop a dynamic Geographic Information System (GIS) - based model of migratory bird movement in Israel and the Middle East. This project is being conducted in cooperation with the United States Air Force Academy in Colorado Springs where the first phase of a GIS-based Bird Avoidance Model has been developed to reduce bird hazards in the United States. GIS tools enable integration and statistical analysis of data available on several dimensions, as well as graphic representation of these data along with associated databases that can be queried by the user. The quality of the data available will allow us to create a multi-dimensional dynamic model incorporating historic data on bird migration, satellite telemetry data, and environmental data. The interaction between meteorological variables, topography and migration intensity, timing, and spatial distribution will be quantified. By understanding the role of changing weather patterns in determining or altering migratory behavior, migration timing, intensity and



The map, part of the development of a GIS-based bird migration model for the Middle East, shows the migration routes of White Storks fitted with transmitters recieved by satelllite over Turkey. This data can be used by the Turkish, Israel, US, NATO Air Forces, to avoid collisions with migrating birds.



These are five White Stork migration routes from their nesting sites in Germany to their wintering sites in Africa, representing 77 white storks that were fitted with satellite tranmitters as a part of a joint German-Israeli research program. Several of these birds can be followed in real-time through the Internet. The second phase of the project is being led by Judy Shamoun-Baranes who is developing a Geographic Information System (GIS) based model of bird migration, integrating all the available data on soaring bird migration in the region into one database. The stork Siegfried (green route). migrated away from the regular route along the eastern part of the Red Sea and was shot by a Yemenite office. The transmitter was later returned to Germany.

orientation can be more accurately predicted then currently possible. GIS is a fairly new tool in the field of ornithology and is mainly used for mapping of bird territories and distribution (Shaw & Atkinson, 1990 and Witham & Kimball, 1996). In the future, this model can serve as a template for expansion to include data from other regions.

Research Objectives

1. To create an empirical migratory bird movement model based on historic data for autumn and spring migration in the region using GIS as the key tool for data integration, analysis, and geospatial display.
2. To study the interaction between meteorological events and the timing and intensity of bird migration on a regional scale.
3. To study the interaction between climatic variables, topography, and soaring birds migrating over Israel on a local scale.
4. To incorporate the biological implications of the meteorological aspects of the project into the GIS-based bird migration model.

Materials and Methods

Biological data:

The most abundant soaring bird species migrating over the region will be analyzed in this study, including the White Stork (Ciconia ciconia) which will be the pilot species for most steps of the project, Honey Buzzards (Pernis apivorus), Lesser Spotted Eagles (Aquila Pomarina), and White Pelicans (Pelecanus onocrotalus).

Following is a list of the data that is presently available for spatial display and analysis.

Motorized glider data from autumn and spring, 1986-1989, used to map individual flock migration routes through Israel, including date, time, coordinates, and altitude of birds when they entered and left each thermal for Honey Buzzards, Lesser Spotted Eagles, White Storks, and Pelicans.

Satellite telemetry data for White Storks as well as several Lesser Spotted Eagles from 1994 to the present including date, time and coordinates of individual bird movements throughout the migratory season. Distance traveled and speed of flight can be calculated from the above information. Though the PTT's (Platform Transmitter Terminal) using Argos satellites theoretically transmit coordinates every 90 minutes or so, the quality of these locations varies greatly. Location classifications A, B, and Z are automatically removed. Only locations 0 (resolution above 1000 meters), 1 (better then 1000 meters), 2 (better then 350 meters), and 3 (better then 150 meters) are used.

Northern Valleys Autumn Soaring Bird Migration Survey from1990 -1999, including number of birds, time, date, species, and station (kilometers from coast). For previous years and other ground surveys, only daily summaries for each station/species are available.

Model Design

GIS will be used as the primary tool for data integration, geospatial display, and analysis

of multidimensional data. The associated biological and environmental databases (attribute data) will be queried using GIS and statistical tools.

The consolidation of the digital database for importation into a GIS is being performed using Microsoft applications, particularly Excel, Access and text editors. Environmental Systems Research Institute, Inc. (ESRI) applications, particularly ArcView with the Spatial Analyst and ArcInfo (UNIX platform), are being used for data integration, spatial, and temporal display, which will be followed by analysis of the relation between different data layers. Initial training in the use of GIS was obtained at the US Air Force Academy in Colorado Springs. Environmental and man-made data that are presently being used includes a digital terrain model (DTM) of Israel developed by John Hall, and hydrological data (source: Digital Chart of the World, ESRI 1993).

Meteorological Analysis

This phase of the project is being performed in cooperation with Prof. Pinhas Alpert and Anat Baharad from the Department of Geophysics and Planetary Sciences, Tel Aviv University. Meteorological data for the regional analysis will be extracted from the NASA data set which provides data at a resolution of 2.5° every six hours, or the National Center for Environmental Prediction (NCEP) data set providing data at a resolution of 1.8° every 12 hours. Both data sets may be used depending on the resolution needed for the analysis. The parameters initially examined in the pilot study included vertical wind (omega), wind direction and speed, temperature, barometric pressure, relative humidity and geopotential height at 850 mb. Wind direction and speed is in the form of x,y vectors and was calculated as in relation to the migration direction as following/opposing wind vector and side wind vectors.

Using satellite telemetry (initially studying White Storks), the distance traveled per day or the estimated hourly speed of migration will be calculated and used for statistical analysis with each weather variable separately, as well as in multiple regression analysis. For the pilot model discussed below, ACE statistical process was used with the aid of Dr. Yoav Dvir from the Mathematics Department of Tel Aviv University.

The soaring bird migration network data, initially for species with a short temporal peak in migration, will be used to examine the relationship between migration timing and intensity and the weather variables found to have a significant effect on migration in the previous section. The first day of arrival in Israel (of 90% of the population) and the peak day of migration each year will be used for analysis. These dates will then be used to extrapolate the migration starting point in Europe several days before the birds reached Israel according to their average daily distance traveled (Leshem & Yom-Tov 1996b). Weather variables will be examined in those regions where it is estimated that the birds were several days previous to arriving in Israel. The Lesser Spotted Eagle will be studied first because of its relatively short peak in migration and geographically limited breeding grounds.

Temperature, barometric pressure, wind direction, and wind speed - obtained from synoptic

stations of the Israel meteorological service - will be used to analyze the interaction between local migratory movements, climatic changes, and topography.

Preliminary Results

Mapping the Data

Digital sources of historic avian data, including stork migration routes obtained through satellite telemetry, motorized glider routes, and the northern valleys autumn migration survey were collected and reformatted for compatibility with GIS data types.

Presently, all satellite telemetry and motorized glider data available have been incorporated as GIS vector coverages. Annual migration paths from satellite tracking were assembled as separate GIS coverages for each year.

Once the data were incorporated into the GIS, it was possible to perform a more rigid quality test. Even following the filtering of satellite locations A, B, and Z several data points were found to be unreliable. Either they were found in points incongruous to the migration path, or too far for a bird to migrate within the designated amount of time. These points were eliminated manually using both text editor tools and GIS editing tools.

The motorized glider data has been overlaid on a DTM of Israel and the satellite telemetry data has been overlaid on a drainage coverage representing permanent water.

By overlaying White Stork migration paths from the satellite telemetry data using GIS, a first draft for recommendations to the Israel Air Force for flight training limitation over Turkey during the migratory months was created (Figure 1).

Pilot meteorological analysis

Migration routes of six White Storks from 1994-1995 were used for the pilot meteorological analysis. The NASA GEOS-1 Assimilation Data Subset was used to provide meteorological data at the 850mb level for Europe to Africa. ACE statistical analysis was used to create a model combining those parameters with the most significant effect on the daily speed of migration. The result of the preliminary test was a strong model combining several meteorological factors. The meteorological variable with the strongest effect on migration speed were: following/tail wind followed by omega (vertical wind), geopotential height, temperature, and finally, specific humidity. As the wind vector in the direction of migration increased, so did migration speed. The presence of a wind vector perpendicular to the axis of migration decreased the speed of migration.

Although these are only preliminary results for six White Storks and two migration seasons the potential for creating such models is clear. This study uses a unique combination of remote sensing of bird migration (satellite telemetry) along large expanses of territory and global meteorological databases that are available to the public, rather then relying on local meteorological services which are often uncooperative or difficult for foreign

researchers to access. A forecasting model based on such data makes regional modeling more then just a concept, but actually possible with resources that are available internationally, some even over the Internet.

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A New Technique for Studying Nocturnal Bird Migration

Adiv Gal
Department of Zoology, Tel Aviv University,
Ramat Aviv 69978, Israel

Abstract

I followed nocturnal bird migration over central Israel by using an acoustic tracking system, which includes a sensitive Pressure Zone (PZM) Microphone, and a Hi-Fi VCR used to record bird calls sounded during migration. Identification of bird calls is performed both by an automatic computerized system (designed by the Acoustic Laboratory at Cornell University) and aurally by an experienced ornithologist using Canary software (written by the Acoustic Laboratory at Cornell University).

The automatic computerized system helped to identify 134 different spectrographs and the experienced ornithologist identified 15 different species. Research results showed two general differences between this project and similar studies conducted in North America. First, the number of calls recorded during spring and autumn migration in central Israel each night was lower than the number of calls recorded in North America. Second, the frequencies of the various bird calls during migration over Israel were much lower than the birds of North America.

Introduction

Nearly all birds that migrate at night give characteristic flight calls. Warblers, sparrows, cockoos, rails, and herons are among the species known to give night flight calls (Thorpe, 1961; Kroodsma et al., 1983; Ranft and Slater, 1987; Evans, 1994, Evans and Mellinger, 1995).

By aiming microphones at the night sky, a volume of sky (dimensions are dependent on microphone design) can be monitored for calls (Graber and Cochran, 1959). Species that regularly form flocks during the day have a night migration call apparently indistinguishable from the daytime call. Other species seem to have a night-time call so different from the daytime call, that it is often difficult to identify the calls (Hamilton, 1962).

The function of night calls apparently are: compensation for lack of visual communication (Kroodsma et al., 1982) to help birds maintain spatial association in flight (Hamilton, 1962), to organize their spacing in order to minimize collisions (Graber, 1968), to help

birds estimate wind direction (Kroodsma et al., 1982), and to encourage birds in migratory condition to take flight (Hamilton, 1962).

This paper describes results and information on the species of birds flying over central Israel during the 1997 fall and 1998 spring migration. The results were compared data obtained in North America (Evans, 1994; Evans and Mellinger, 1995; Evans and Rosenberg, 1997).

Methods

Nocturnal flight calls of migrating birds were recorded during the 1997 fall migration and during the 1998 spring migration, for a total of 100 nights. The station was located in Yavne (34045'E, 31052'N), Israel.

The PZM microphone was used in conjunction with a high-fidelity video cassette recorder to enable directional sound pickup and inexpensive recording of avian night-flight calls over a long period. The microphone was designed to be especially sensitive to the 2 - 10 kHz range. The Hi-Fi VCR allowed for ten hours of continuous recording of sound from the night sky and could be programmed for regular nightly operation.

All the records (a 102-night total of 1,020 hours) were first analyzed automatically by a special detector (written by Mr. Harold Mills, Cornell University) to detect calls above 2 kHz (total of 9 hours). These calls contained background noises and bird calls. Analysis of the distinction between bird calls and background calls was carried out using the Canary Software Program (Charif et al., 1995) and using ShowGrams (a Matlab program). Spectrographs of calls presented in this paper were produced from calls digitized with a 22254 Hz sampling rate and processed using a 256 point FFT, 128-point frame size, 87.5% overlap, and Hanning window (frequency resolution 86 Hz, time resolution 0.72 msec, analysis bandwidth 700 Hz).

Mr. Amir Balaban, Mr. Adi Ganz, Mr. Gidon Perlman, and Mr. Rami Mizrachi, all experienced birdwatchers, identified the calls by aural comparison.

Results

For only 25 of in 40 nights (62.5%) I detected 742 calls during the 1997 fall migration. By using the Canary Software Program I identified 66 different spectrographs. Aurally I identified 7 species. During the 1998 spring migration I detected 1463 calls on 36 out of 62 nights (54.4%). Using Canary, I identified 90 different spectrographs and aurally I identified 14 species (Table 1). In total I detected 2,025 calls averaging almost 21 calls per night.

Of the 15 identified birds five species were transients and wintering birds, four species were resident, two species were transients and summering birds two transients one species was transient, wintering, and resident and one species was wintering (Table 2).

Table 1: *Summary of the number of spectrographs and identified calls recorded during 1997 fall migration and 1998 spring migration.*

Month/Year	8/1997	9/1997	10/1997	11/1997	3/1998	4/1998	5/1998
Total no. recording nights	19	6	10	5	10	30	17
Total no. detection nights	5	5	10	5	7	19	5
Total Calls	151	199	156	236	375	955	133
No. of spectrographs	9	7	28	23	36	51	7
No. of species identified aurally	2	3	5	5	3	7	3
No. of spectrographs and species identified aurally	11	10	33	28	39	58	10

Table 2: *Average frequencies and duration of the identified species (+ S.D.)*

Name of species	Avr. upper range of the calls (kHz+S.D.)	Avr. lower range of the calls (kHz+S.D.)	Duration (mS+S.D.)	No.
Galerida cristata	4.18 + 0.31	6.80 + 0.13	158.65 +42.78	4
Burhinus oedicnemus	3.09 + 0.16	5.71 + 0.12	96.75 + 8.73	270
Carduelis chloris	2.83 + 0.36	4.62 + 0.27	106.21 + 60.27	13
Vanellus spinosus	3.02 + 0.18	6.27 + 0.76	88.75 + 2.50	262
Merops apiaster	1.79 + 0.24	2.51 + 0.22	96.13 + 20.90	78
Apus apus	3.8	6.37	313	
Coccothraustes coccothraustes	2.94 + 0.02	6.48 + 0.29	7.79	2
Tringa ochropus	3.37 + 0.06	4.89 + 0.50	16.17 + 5.58	6
Motacilla alba	3.81 + 0.48	6.49 + 0.62	42.27 + 8.17	64
Phylloscopus collybita	3.01 + 0.52	4.84 + 0.19	54.30	2
Anthus pratensis	4.50 + 0.43	6.74 + 0.41	126.76 + 29.83	35
Emberiza hortulana	3.44 + 0.23	4.69 + 0.32	44.86 + 9.71	16
Motacilla flava	3.64	5.23	152.2	
Nycticorax nycticorax	1.78 + 0.24	2.41 + 0.29	91.04 + 0.29	26
Fringilla coelebs	2.70 + 0.51	4.68 + 0.22	74.73 + 18.26	64

Table 3: *Frequency changes of species no. 56 in relation to altitude and temperature during April 1998 in central Israel.*

Date	Recording hour	Altitude (above ground level)	Temperature (C0)	Frequency (kHz)
1/4/1998	01:33	760	10	3.36 - 4.43
7/4/1998	01:23	570	17	3.35 - 4.64
9/4/1998	23:56	570	12	3.40 - 4.52
10/4/1998	01:28	760	20	3.25 - 4.60
16/4/1998	01:32	570	32	3.69 - 4.67
17/4/1998	00:48	760	15	4.20 - 4.97
26/4/1998	01:15	570	25	3.79 - 4.92
30/4/1998	01:23	570	13	3.62 - 4.86

In an attempt to check the relationship between frequencies, altitude, and temperature, I selected species no. 56 whose calls were detected over 300 occurances during April 1998 in central Israel (Table 3).

There was no relationship between call frequencies of this species and any of the above parameters.

The numbers of calls recorded after sunset during fall migration 1997 and spring migration 1998 are shown in Figure 1.

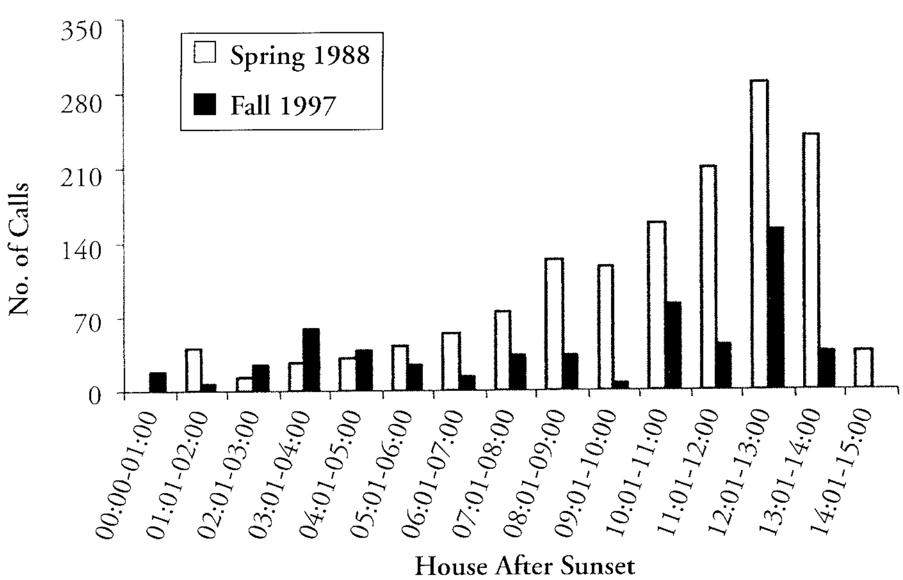

Fig. 1 *The numbers of calls after sunset that were detected during fall migration 1997 and spring migration 1998.*

The difference between the number of calls that were recorded was significant between the seasons (Wilcoxon Matched Pairs Test, $p = 0.0097$, $z = 2.588$). In both seasons I recorded most of the calls 12 to 13 hours after sunset. However, during the 1998 spring migration 12 to 13 hours after sunset means between 1 to 2 hours after sunrise (there is an average of 11:08 hours between sunset and sunrise), while during the 1997 fall migration 12 to 13 hours after sunset means up to one hour after sunrise (then is an average of 12:05 hours between sunset and sunrise).

Discussion

In general, research results showed two differences between this project and similar studies conducted in North America. First, the number of calls recorded during spring and autumn migration in central Israel each night was lower then the number of calls recorded in North America (Evans, 1994, Evans and Mellinger, 1995). Second, the frequencies of the various bird calls during migration over Israel were much lower than among the birds of North America ((Evans, 1994, Evans and Mellinger, 1995).

I cannot link the difference of the number of calls recorded during spring and autumn migration in central Israel to those of North America or the difference of frequencies of the various bird calls during migration over Israel and over North America to geometrical factors that depend on the range and volume of the microphone beam in which the birds can be heard (Black, 1997c) because I used the same microphone that Evans used in his research (Evans, 1994, Evans and Mellinger, 1995).

The vast number of unidentified calls might be explained as follows: part of the species have a night migration call so different from the day call that it is often difficult to identify the calls (Hamilton, 1962). In addition, and to emphasize the difficulty of identifying the night flight calls, I failed to compare spectrographs of the same species that were recorded in Europe to the same species that were recorded in Israel.

For example, I found that spectrographs of Tringa nebularia that were recorded in Europe were below 3 kHz for duration of 100 msec and spectrographs of the same species that were recorded in Israel were above 3 kHz for duration of 50 msec (Gal et al., 1998).

The difference between number of calls recorded each night between central Israel and north America might be explained as follows: Only 38 % of the nocturnal spring migration in central Israel was concentrated below 800 meters above sea level (results from the Latrun radar (Gal, 1999), the range at which the PZM microphone can not detect calls. In contrast to the Latrun radar result, most of the passerines in North America fly below 500 meters above sea level (Evans, 1994, Evans and Mellinger, 1995), the range at which the PZM microphone can detect calls.

Based on results from the Latrun radar (Gal, 1999) and from fig. 1, I can support the finding that flight level during the 1998 spring migration over central Israel during most night's hours was higher than 1,000 meters above sea level (the efficient range of the

PZM microphone). Moreover, after sunrise the birds started to land (meaning a lower flight level) to look for good habitat to rest with the result that I was able to detect more calls.

The differences between the frequencies from North America (Evans, 1994, Evans and Mellinger, 1995) and central Israel might be explained as follows: 1) the actual absorption of acoustic energy in the air increases in magnitude as the square of the frequency. The strong dependence of atmospheric absorption on frequency causes the atmosphere to act as a low-pass filter, the steepness of filter characteristics increases with the distance of transmission (Griffin and Hopkins, 1974; Kroodsma, et al,. 1982). Hence, the combination of high flight level of migrating birds during spring migration in central Israel (Gal, 1999) and atmospheric traits allows the detection of more low frequencies and less high frequencies calls. 2) DNA - DNA hybridization indicates that all the identified species from North America (Evans and Rosenberg, 1997) and from this research are close enough to form single family, comprising two subfamilies: Fringillinae and Emberizinae (Sibley and Monroe, 1990). Hence, all the species from North America that are mentioned in Evans and Rosenberg (1997) belong to Emberizinae. The identified species from central Israel belong to Fringillidae (Fringilla coelebs, Coccothraustes coccothraustes and Emberiza hortulana), Sylvidae (Phyllocopus collybita), and Passeridae (Motacilla alba, Motacilla flava and Antus pratensis).

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WSR-88D/98D: Operational Capabilities And Applications, Weather And Biological Targets

Leslie R. Lemon
Radar, Severe Storms, & Research Meteorologist
Phone: 816-373-3533
E-Mail: lrlemon@compuserve.com

Abstract

With the WSR-88D full production complete and system meteorological applications now commonplace, there remains a dearth of information on system operational capability and applications when it comes to biological targets. Only recently has the systems insect and bird detection abilities been recognized and those begun to be exploited. Even so, data have been collected in all 50 states and some international localities and a variety of biological targets have been sampled and information gathered about system potential in that regard. Some of that potential will be briefly explored here. However, the system has also demonstrated considerably more meteorological capability than any other current operational weather radar, in part because of a very wide dynamic range enabling detection of reflectivities from less than -30 dBZ to greater than +90 dBZ. Data are collected from the surface to 21 km and to a maximum range of 460 km with up to 14 elevation scans every 5 minutes. Additionally, the system also provides measurement of the three base moments simultaneously (Reflectivity, Mean Radial Velocity, and Velocity Spectrum Width), algorithm processing, and creation of related derived products totaling more than 75 displayable forms. The system processes these base data via the pattern recognition algorithms, and produces derived products designed to output specific information related to storm characteristics such as storm tracks, storm hail probabilities and maximum hail sizes, trends in critical storm characteristics, mesocyclones, and other phenomena. Rainfall estimates for varying accumulation periods also are provided. Product types and applications are also briefly discussed. A closely related but modernized version of the radar, the WSR-98D, is now entering production, and will have all these capabilities and even more.

Emphasis is placed on capabilities and applications of the WSR-88D/98D for a wide variety of meteorological and biological targets. These include optically clear air, frontal, and cloud detection, stratiform precipitation including excellent snow detection capability, flash flooding, severe storms, and less well-known detection of insects (aerial plankton), birds, and bats. Achieved skill scores of National Weather Service (NWS) operation at the

Weather Service Forecast Offices (WSFO) are considered. Evidence will be introduced that suggest similar skill scores may be possible in the future for biological target identification and its potential use in preventing Bird - aircraft collisions.

1. Introduction

As part of the major undertaking of modernizing the National Weather Service (NWS) of the United States, the Weather Surveillance Radar 1988-Doppler, or WSR-88D network has been deployed throughout the U.S., Alaska, Hawaii, and a few Department Of Defense (DOD) sites in the Pacific Rim (Heiss et al. 1990, Alberty and Crum, 1991). During the first few years of operation by the NWS Weather Service Forecast Offices (WSFO) the radar has demonstrated considerably more capability than any other operational weather radar and has proven to be a very effective tool for use in storm analysis and the issuance of warnings, statements, and short term forecasts (e.g., Lemon and Parker, 1998; Lemon, 1998). This is, in part, because it provides a very wide dynamic range (95 dB) enabling detection of reflectivities from -32 dBZ to +95 dBZ, large peak power transmission (750 kw), high resolution (0.95 degree beam, and .13 nm, .25 km pulse volume depth for Doppler measurements and .54 nm, 1 km for reflectivity) and low side lobes (-28 dB down) (see Heiss et al. 1990, for engineering details). Data are collected in volume coverage patterns (VCP) from the surface to 21 km and to a maximum range of 460 km using 9 to 14 elevation scans from 0.5 degrees to 19.5 degrees every 5 or 6 minutes, in precipitation mode. In clear air mode data are collected from 0.5 degrees to 4.5 degrees every 10 minutes. A long pulse (.39 nm, .75 km) VCP is also available in clear air mode providing even greater sensitivity. Additionally, the system also provides measurements of the three base moments simultaneously (Reflectivity, Mean Radial Velocity, and Velocity Spectrum Width), processes these data and creates related derived products totaling more than 75 displayable forms. In addition, the system is designed with considerable operational flexibility and capability. As mentioned above, a follow-on system, the WSR-98D, will use a much faster, more capable, open system computing structure, a new signal processor, and other enhancements to potentially far exceed the 88D accomplishments to date.

In this paper, in addition to a presentation of the capabilities and applications of the WSR-88D/WSR-98D for a wide variety of meteorological phenomena, the radar's capabilities for biological target detection will also be introduced. It will be shown that the system has easily detected birds, bats, and insects, even at considerable range from the radar. A great field operational potential in this area will also be introduced. But, its widely demonstrated weather detection abilities such as in optically clear air, frontal and cloud detection, stratiform precipitation including excellent snow detection capability, and other more dramatic phenomena such as flash flooding, will not be neglected. Applications to severe convective storm situations, for which the system is particularly adept, are also considered. Product types and applications will also be briefly discussed.

Before addressing the above topics, the reader should be aware of the four major WSR-88D/98D functional components: the Radar Data Acquisition (RDA) unit or radar itself, the Radar Product Generation (RPG) unit which processes the meteorological algorithms and generates the displayable products, the Principal User Processor (PUP) or operator work station, and the communications system tying the above components and network together. Each RDA is uniquely associated with one RPG by a full duplex wideband communications wire cable, fiber optic cable, or Microwave Line-of-Site link. Our perspective in this paper is from the PUP where the meteorologist performs his/her duties of product request and display, data interpretation, decision-making, and warning, statement, and forecast formulation. Each PUP is "associated", with one and only one RDA/RPG couplet but may act as a non-associated PUP, via dial-up lines, with any other radar in the network. Through the use of internal PUP and RPG passwords, access to RPGs may be restricted in order to manage system resources and network communications costs. As an associated PUP, it is connected to an RPG by a dedicated line over which products, status, and other information flow to the PUP from the RPG and over which status and other information flow from the PUP to the RPG. As a non-associated PUP, the operator may request selected products (a temporary dial-up connection) from any other radar in the network as permitted. More detail on all the above may be found in Alberty and Crum, (1990, 1991, 1992); Heiss, et al., (1990); O'Bannon and Klazura (1990); and FMH-11 (1990).

2. Algorithms and Products

In the course of our subsequent discussion we will mention certain WSR-88D algorithms and products. A brief review is included here but more is available (e.g., Klazura and Imy, 1992; and in Lemon et al., 1992). A distinct strength of the WSR-88D is the meteorological pattern recognition and processing capability of the system (Fig. 2). These computer programs are called "algorithms" (FMH-11, 1990). Each is geared toward producing a PUP displayable "derived" product that either answers an operational question (eg., the speed and direction of storm motion or Storm Track Information, STI) or provides an alternate, processed volumetric view of base data designed to help measure storm severity (eg., Vertically Integrated Liquid, VIL; Green and Clark, 1972). Most, but not all, of the current suite of algorithms are designed for application to the convective storm. However, many more are being developed including those for biological target detection. These algorithms, while in various stages of maturity, provide useful information which hasten data interpretation as well as partially lift the burden of complex base data interpretation. These algorithms and related products are essentially "guidance" similar to synoptic scale numerical model guidance. Typically the operator determines, within limits, the "problem of the day" and selects those algorithm outputs (products) that address that problem. A few of these algorithms (and products) include the HDA, STI, and the hydrometeorological algorithms. (The entire suite of algorithms is designed to avoid embedded constants and use instead, site adaptable parameters allowing the operator

or system management to "tune" the algorithm to the radar's location, climatic regime, session, or air mass.)

There are, quite literally, hundreds of products selectable from the PUP during each volume scan. (See figure 2 for some of the principal, derived, product types.) When considering surveillance type (covering a 124 nm, 230 km, radar radius) base products (Reflectivity (R), Mean Radial Velocity (V), and Velocity Spectrum Width (SW)), the operator will most often find the variety of resolutions and data levels provided by these polar coordinate images effective. (In contrast to Canada, in the United States the NWS has not found it necessary to use CAPPI products for operational purposes.) Reflectivity products are available in resolutions of .54 nm (1 km), 1.1 nm (2 km), and 2.2 nm (4 km). For the lower resolution products the maximum data value is displayed. Doppler base products are available in .54 nm (1 km), .27 nm (.5 km), and .13 nm (.25 km); however, the higher resolution products cover restricted ranges from the RDA. In contrast to reflectivity, for display purposes, every fourth measured velocity resolution volume (.13 nm, .25 km) is used to code the lesser resolution .54 nm (1 km) Doppler value. When the concern is diagnosing the velocity structure of a non-convective, stratiform precipitation area associated with a synoptic disturbance, the above constraints are of little effect. However, when using the data to quickly evaluate those convective storms within the area of responsibility, which contain shear, the Storm Relative Mean Radial Velocity Map (SRM) surveillance product is used. (Here, the product color selection, which is adaptable, is also important to highlight shear and strength; Lemon et al. 1992.) This product not only corrects for storm motion, allowing vortical flow fields to be more apparent, but also selects the maximum measured value to code the display value. If a radial shear is detected via the SRM, then the storm containing the shear can be examined in still greater detail in search of a possible severe thunderstorm-associated mesocyclone (Burgess and Lemon, 1990). These mesocyclones are almost always attended by severe weather and occasionally by tornadoes. When diagnosing the strength of a mesocyclone, the maximum measured velocity in the signature as well as the surrounding reflectivity storm structure are of great import in the evaluation of severe weather and tornado potential. In order to do this, certain "window" (27 by 27 nm, 50 by 50 km, square) products centered on the storm or region of interest, can be requested. Either the Severe Weather Analysis (SWA) product or the Storm Relative Velocity Region (SRR) product at the appropriate elevation angle is used. The SWA product is a four panel (quarter screen) product containing presentations of the three base products and one derived (at their respective, maximum, radar measured resolution) of Severe Weather Analysis Reflectivity (SWR), Severe Weather Analysis Velocity (SWV), Severe Weather Analysis Spectrum Width (SWW), and Severe Weather Analysis Radial Shear (SWS). The SRR product displays the storm relative, maximum measured velocities at a product resolution of .27 nm, .5 km. Often, and quite effectively, surveillance or window products from increasing elevation angles are displayed simultaneously in quarter screen mode to examine three dimensional reflectivity and velocity structure.

Space does not permit further detail, however, a brief listing and explanation of other

more useful products for convective storm application follows.

- Hail Detection Algorithm (Hail Index)-HI- The improved hail product still retains its name, the Hail Index (HI) product, but the algorithm providing product information is now the "Hail Detection Algorithm" (HDA). HI product characteristics have also changed with the new HDA output. Probability of Hail (POH) is calculated by the algorithm and it uses an index called the Severe Hail Index to calculate the Probability of Severe Hail (POSH) and Maximum Expected Hail Size (MEHS).

The HDA searches for high values of reflectivity above the freezing level. The reflectivities used are the maximum reflectivities of cell components, as long as those values are above the freezing level. Values below that level are ignored. For the calculation of POH, the location of the heighest reflectivity of at least 45 dBZ above the freezing level is found. The greater the height above the freezing level, the greater the POH. In the calculation of POSH and MEHS, reflectivities greater than 40 dBZ that are present above the freezing level are used. In addition, a weighting factor is used, such that the greater the reflectivity value above 40 dBZ and the greater the altitude of this value, the greater the weighting factor. Reflectivities greater than 50 dBZ and those at altitudes higher than the altitude of the —20o C isotherm, carry the most weight.

This algorithm implements what we now know about wet hail growth within updraft regions of supercooled liquid water. In order to work properly, the heights of the 0o C and the —20o C must be entered at the Unit Control Position (UCP) and must be updated as local sounding information is updated..

- Mesocyclone-M- This product and related algorithm is a tool for the automated detection of mesocyclones within about 110 nm (204 km) of the radar. As the radar is installed in areas significantly different than the U.S. Great Plains, some site adaptation will have to be performed, although, as stated above, this can be done easily once the modified algorithm threshold values have been established. M is also effectively used as an overlay on other products (e.g., R, V, VIL, SWA, SRM, etc.).

- Storm Cell Identification and Tracking — (SCIT) - The Storm Track Information (STI) product is feed by the SCIT algorithm. It is a robust and capable algorithm. The SCIT algorithm uses 7 adaptable thresholds. The algorithm begins with finding each area, storm, or cell via the 30-dBZ-reflectivity threshold. But it then searches within this region for reflectivities of 35 dBZ or larger. Upon finding values of this magnitude, it then searches for reflectivities of 40 dBZ and so on at 5 dBZ increments up to and including 60 dBZ. Thus, the algorithm searches and retains reflectivity cores and is therefore effective in identifying cells in areas and lines. As with virtually all algorithm values, these are fully changeable and adaptable. This process is carried out at each sampled radar elevation angle of the active Volume Coverage Pattern (VCP). Centers are then determined for each of these areas or reflectivity cores. Attempts are then made to correlate these areas and their centers with other areas and centers in each of

these radar sampled elevation angles or cuts. When centers and cells are correlated vertically, storms are identified. This algorithm can automatically identify and track up to 100 storms each volume scan. Storms are algorithmically numbered in a manner such that it is easier to tell the age of each storm. Current storm positions, past track, and future positions are updated and displayed (as requested) each volume scan. The operator can choose the number of cell identifiers they wish to display. For each storm, the algorithm measures and reports its errors in the attribute table and, if necessary, it will limit future cell motion forecasts. The number of storms displayed in graphical products and listed in the attribute tables are adaptable and operator selectable in order to control display clutter and product transmission times.

In one test of SCIT, over 5400 cells were successfully identified without a failure. The improved algorithm performance has improved performance of several downstream algorithms such as the storm relative velocity products, the hail algorithm, cell based VIL production, cell trends, WER, etc.

- Cell Based VIL - The Cell Based Vertically Integrated Liquid "product" is not a replacement for the current Cartesian grided VIL product; it still exists as a stand-alone product. However, the Cell Based VIL has been added and is intended to overcome some of the weaknesses of the grided product. Those weaknesses include an underestimation of the actual VIL when the storm is either moving at a high rate of speed or is tilted in the vertical, as are some severe storms. In those cases one portion of the storm may be in one grid box while the rest of the storm may be in an adjacent grid box. However, Cell Based VIL links the storm reflectivity core in the vertical through all slices that sample the storm. Thus, Cell Based VIL is more conservative from volume scan to volume scan. Additionally, Cell Based VIL uses the heighest reflectivity bin whereas the grided product uses a three-bin average and the Cell Based VIL is not truncated at 80 kg/m2 .

Cell Based VIL appears as a single value for each SCIT-identified storm in the Composite Reflectivity Combined Attribute Table and in the Cell Trends, which are both discussed below.

- Cell Trends -The Cell Trends is a very useful addition to the forecasting or nowcasting tools that radar can provide. Cell Trends is a derived graphic display generated from data in the Storm Structure (SS) product. It uses a full screen display that is divided into four graphs of radar algorithm derived storm characteristics. Each graph displays the changes in a number of parameters with time for up to 10 volume scan. The product includes changes in the height of the three-dimensional storm centroid, the height of the maximum reflectivity, and the base and top of the 30 dBZ reflectivity region. It also includes changes with time of both the POSH and POH from the hail algorithm output, changes in Cell Based VIL with time, and the change in the magnitude of the storm maximum reflectivity.

Through the use of this easily requested display, the operator can obtain, at a glance, the change in overall storm intensity. The operator can also anticipate changes in details of the storm severity and thus issue more accurate and detailed warnings.

- VAD Wind Profile-VWP- A product that provides a very useful estimate of the mean horizontal winds with height at up to 30 adaptable intervals (typically .6 km apart) where sufficient radar encompassing echo exists. Due to the very high sensitivity of the radar to refractive index gradients, good estimates of the winds are provided in the convective boundary layer, often wherever clouds are present, and sometimes even in areas without cloud in addition to precipitation areas.

- Echo Tops-ET- This Cartesian image product (also available in contour form) provides a good estimate of the tops of the 18 dBZ (adaptable threshold) precipitation echo.

- One Hour Precipitation-OHP, Three Hour Precipitation-THP, Storm Total Precipitation-STP and the User Selectable (period) Precipitation (USP) accumulation products. These polar coordinate image product displays provide either running totals (OHP, STP, USP) or a clock hour (THP) accumulation estimate and have proven to be effective and are used to issue flash flood or river flood statements and warnings and for water management.

Even accurate, high-resolution product data is meaningless without a context. The WSR-88D/98D PUP provides that context. All of the geographically based image products may be paired in adaptation data with one or more of a variety of background maps which are appropriate to the product or its intended use. For example, maps of rivers and/or river basins are available, airways, navigational aids and airports, countries, counties, cities, and highways are also available, just to name a few. The operator may also easily add or delete additional maps to displayed products.

There are three primary methods for an associated PUP to request products from the RPG. Those methods are: the Routine Product Set (RPS) list, the One Time (OT) request, or the Product-Alert Pairing. The RPS is a list formulated at the PUP and transmitted to the RPG requesting up to 20 products for routine transmission to the PUP. Most of these products are requested for generation and transmission every volume scan, but may be requested much less often. An OT request is made to supplement the RPS as needed but can be made with a "repeat count" directing the RPG to produce the requested product as selected for up to the next 9 volume scans. In PUP adaptation data the operator may request transmission of a selected product whenever an operator designated alert is identified by the RPG.

3. Clear Air Detection and Applications

As mentioned previously, the WSR-88D/98D transmits large peak power quantities at high resolution and is a very sensitive radar, and in fact, is capable of detecting -10 dBZ at 27 nm (50 km). The S band (10 cm wavelength) radar has proven to be a better system for clear air detection than the C band (5 cm) radar because detection is a function of the wave lengths of refractive index gradients (atmospheric density differences). Reflections

of this type are called Bragg scattering. This is why profiler radars use the P band (40-50 cm). Thus, as compared with other current weather radars, the combination of high sensitivity, large dynamic range, higher power transmission, and wavelength make the WSR-88D/98D particularly suitable for the task of clear air (as well as severe storm) and biological target observations. Whenever atmospheric processes produce refractive index gradients- density gradients- then very often sufficient power return, (again, Bragg scattering) for clear air radar observation is achieved. Fortunately, this is often the situation that accompanies atmospheric boundaries, clouds, and precipitation processes. Of course, if particulates or aerosols are present, even more power return occurs. This is the case in many instances where aerial plankton and predatory birds are present as well (Russell and Wilson, 1997). However, at times cloud and particularly fog will not produce much reflectivity when processes are mostly advective and unaccompanied by sufficient density gradients or particulates. Strictly speaking "cloud" is not detected. Most often processes leading to, but very often prior to, cloud formation will produce significant return in clear air VCPs. For example, clouds of all types, including cirrus, will often produce detectable echo, even in the less sensitive precipitation modes of system operation. (The system currently uses two volume coverage patterns [VCP] specifically for clear air detection and two for precipitation detection). At times when visually only scattered cloud is seen, a relatively contiguous layer is detected by the WSR-88D in the form of a ring centered on the radar (Lemon and Quoetone, 1994). The inner edge of the ring is very near cloud base (due to the slant range-height relationship) and the outer edge is near cloud top. It is speculated that actual cloud base will be somewhat higher than radar echo base and cloud top somewhat below echo top. Generally, there is a marked enhancement in clear air boundary layer reflectivity occurring with sun set and some further increase during the fifteen or twenty minutes following. The cause is probably relates to two factors. One is the increase in nocturnal aerial plankton and predatory birds as well as the establishment of the low level inversion and corresponding increase in beam bending (refraction) at the interface. As reflectivities increase it is sometimes difficult to discern cloud from precipitation. It appears that reflectivities of 0 dBZ and less are usually due to refractive index gradients (often cloud), however, this threshold may vary at times especially in the presents of aerial plankton-enhanced reflectivities after sunset. WSR-88D reflectivities are often 5 to 15 dBZ higher than those measured with a WSR-57. This difference is the result of primarily higher resolution (smaller pulse volume), but contributed to by higher power transmission, and continuous automatic calibration.

In most mid latitude locales, particularly when sufficient atmospheric water vapor, insects and birds are present, clear air return is best detected for about the 9 warmest months of the year. When surface conditions are cold and dry, little optically clear air return is measured. However, even in January in Oklahoma during a recent cold frontal passage, the front itself was detected while the radar was in a clear air VCP and the front was within about 20 nm (37 km) of the radar. Dewpoints ahead of the front were in the 30's F (0-5 degrees C) and temperatures were mild, upper 40's F (5-10 degrees C). Behind

the front, temperatures cooled into the 30's F (1-4 degrees C). Even the "dry line" (a boundary separating warm moist air from warm dry air; Schaefer [1974]) is detected rather well. In one case examined by the author, surface conditions were such that dewpoints and temperatures ranged from the 40's F (5-10 degrees C) and mid 80's F (25-30 C) respectively behind the dryline; to the 60's F (teens C) and near 80 F (~26 C) respectively ahead of both the dryline and cold front. Behind the cold front, dewpoints and temperatures fell into the 35 to 40 F (around 3 C) and 65 to 73 degree F (around 20 C) range respectively. Radar returns in this case were rather typical. Reflectors with meteorological boundaries appear to be both Bragg scattering and biological targets aided by convergence along these boundaries (Russell and Wilson, 1997). Ruthi, et al., (1993) discusses operational WSR-88D detection of these and other boundaries.

Due to the rarity and severe weather association of thunderstorm gust front detection with prior generation operational weather radar, radar "thin lines" were often used as indicators of impending severe weather (Battan, 1973). However, similar outflow boundaries are often detectable with the WSR-88D when non-severe and severe storms alike are relatively near the radar (within about 110 km). The gust front importance to storm propagation, dynamics, sustenance, and future development has long been emphasized in the literature. Similarly, it has been found in WSR-88D applications in the U.S. that detection, tracking, and intersection of these boundaries enable (among other things) short term (1 to 3 hour) forecasts for storm development (Ruthi et al., 1993). Once again, as indicated above, these atmospheric discontinuities owe their appearance to convergence in the boundary layer augmenting Bragg scattering and presence of aerial plankton and predators.

Here, we have presented the radar systems ability to detect cold fronts, dry lines, and thunderstorm gust fronts. However, there are a variety of other boundaries that have been detected to date (Ruthi et al., 1993). For example, warm and stationary fronts, mesoscale convective system "bubble" boundaries, land-sea, lake, and even river breezes have also been observed. Additionally, a number of other boundaries of unknown origin, which would not have been otherwise detected, have been identified. Some of these appeared to have been important to cloud formation and weather events but others had no observable influence. Of course the importance of these poorly understood "discontinuities" can not be derived without first knowing of their existence and then not without other supporting conventional observations and analyses. Ruthi et al., (1993) have even derived the existence of apparent "atmospheric discontinuities" aloft which had no observed surface affects and no known origin. The interpretation of these linear reflectivity (and sometimes velocity) features as boundaries must be done with caution, however, without other supporting, independent observations, especially because we know that insects, birds, and other particulate matter can also easily produce a pronounced WSR-88D/98D displayed return. However, owing to the fact that boundaries of all types are so important in many meteorological situations and, as stated, so readily detected by the WSR-88D/98D, the radar has proven to be a boon to nowcasting for those who have it.

Especially in the southwest U.S., the radar has also been used in the detection of dust and sandstorms. These disturbances are not uncommonly attended by a radar detectable discontinuity heralding the arrival of a wind shift accompanied by rapidly escalating winds and airborne dust or sand. At other times, winds will more gradually escalate with large scale disturbances and boundary layer reflectivities will increase with increasing dust, sand, and even atmospheric debris content. Of course, if aerosols are extremely small, radar reflectivity will not appreciably increase.

4. Stratiform Precipitation Applications

Often, the development, increase, and lowering of cloud aloft and subsequent development of precipitation aloft can be well observed through proper use of the radar reflectivity data (Lemon and Quoetone, 1994). In these situations the lower levels of the atmosphere may be relatively dry and as the precipitation falls it will rapidly evaporate (often the case during developing snow situations). However over time, this process both cools and moistens the atmosphere at progressively lower levels until finally the precipitation reaches the surface. This process too, is well followed by the WSR-88D because of its sensitivity. In fact, the rate of decent (or gradual lowering) of the precipitation base may be calculated, resulting in estimates of when surface precipitation will begin. Note that the application of the radar observed "donut" or ring and wedge geometry is very helpful here, see Lemon and Quoetone, 1994. That is, the nearest or inside edge of the wedge or ring is the base while the outer edge of the precipitation ring or arch corresponds to the cloud or precipitation top. The wedge is created when cloud or precipitation is gradually advancing and lowering from a preferred direction rather than developing in situ. It should also be noted here that the same system sensitivity to cloud and clear air phenomena manifests itself in excellent snow detection and even light snow detection capability (Ruthi et al., 1993). When surface temperatures are above freezing, the WSR-88D observed bright band can also be used in a similar manner to determine if, when, where, and how rapidly the surface precipitation type changeover will occur (Lemon and Quoetone, 1994). In fact, because the height of the maximum reflectivity is output by the STI and included in the associated attribute table, this information can be used to determine some of the above listed characteristics in stratiform situations during the existence of the bright band. (Of course the application to aviation icing is apparent). The Echo Top product can be used to note precipitation tops over the entire area at a glance. Also, via high resolution reflectivity data, the existence of banded structures, slantwise convective instability, and embedded convection can be discerned and tracked through the use of the STI overlay as well as through the use of the system time lapse capability. The precipitation accumulation products will continuously portray hydrometeorological information and regions of threat due to excessive rain.

In these same situations the measured radial velocity data can be used for determination and progression of a number of atmospheric flow phenomena (Ruthi et al., 1993; Lemon and Quoetone, 1994). Early in the development of cloud and precipitation aloft, the

operator can determine the direction, strength, and presence of jets, thermal advection, and rate of change of each of these through either the interpretation of the radial velocity products or the application of the VAD Wind Profile product. As the precipitation is present over a significant depth of the troposphere, then an essentially continuous record of the development and changes of the winds aloft profile and temperature advection can be obtained. Not only are low level jets and their changes apparent with time, but also the characteristics, height, and rate of change in the frontal surface aloft can often be monitored. For example, that surface and its character are often portrayed by a northeasterly low level flow rapidly shifting to a southwesterly flow aloft as a surface cyclone passes to the south. This flow profile can be compared to the synoptic numerical guidance and any error in those forecasts noted. Cold air depth can also be measured. Additionally, the winds aloft and regions of turbulence can be measured and monitored and relayed to the pilot during a pre-flight briefing, while in route, or while awaiting take-off. The information supplied to hot air balloonist, hang gliders, etc., is of utmost value as these aviators are influenced greatly by the magnitude and direction of even the lightest winds. The velocity Spectrum Width is another good product for aviators for the observation of regions or layers of probable turbulence aloft (Lemon, 1999).

5. Precipitation Estimation

Floods cause an average of nearly 200 deaths and property damage approaching two billion dollars in the United States each year. Essential to the preparation of accurate and timely flash flood and flood warnings is the availability of reliable rainfall estimates. The very great variability of rainfall, especially in convective environments, makes accurate aerial estimates of rainfall difficult even with a relatively dense network of rain gauges. The hydrometeorological processing algorithms of the WSR-88D/98D provide rainfall estimates over a 124 nm (230 km) radius in radar polar coordinates for varying periods of time. Specific image and alphanumeric products available to the forecaster, as mentioned, include the OHP, THP, STP, and the USP. The OHP, STP, and USP products are updated each volume scan (every 5 or 6 minutes, depending upon scan strategy selected). THP is updated every clock hour. The precipitation processing algorithm uses, as a default, a Z-R relationship of Z = 300R1.4, where Z is the equivalent reflectivity factor in mm6m-3 and R is rainfall rate in mmhr-1. As mentioned earlier, values such as these are operator adaptable, however they have not been found to be critical. This is because the aerial and storm Z-R variability tend to compensate for each other permitting computation of accurate basin averages. These basin averages are computed externally to the radar system at River Forecast Centers through the use of non-PUP-displayable Digital Precipitation Data Array products produced within the RPG.

The radar rainfall estimates have been found to be extremely useful to forecasters. In most cases, the estimates are accurate and representative, although certain meteorological environments lead to underestimation or overestimation of precipitation accumulation. An environment characterized by great instability and limited low level moisture typically

will result in storms with low precipitation efficiency. The precipitation processing algorithm tends to overestimate rainfall accumulations in those cases, particularly at great ranges from the radar site, where the radar beam intercepts the storms several thousand feet above the ground. The high reflectivities detected by radar well above the surface frequently are indicative of hail rather than very high rainfall rates. On the other hand, an extremely moist and marginally unstable environment tends to support relatively low-topped storms, which are highly efficient precipitation producers. Frequently, the precipitation algorithms underestimate rainfall from such storms. Once again, the least accurate estimates tend to be those far away from the RDA. In this case, the radar overshoots the highest storm reflectivities. In either of these cases there are algorithm adaptable parameters designed to correct for or partially compensate for these inaccuracies. However, most of the major flooding events in the central United States occur with mesoscale convective clusters which are handled well by the WSR-88D precipitation estimation algorithm. Additionally, when integrated with real-time gage measurements (as the current design permits), rain gage estimates will allow automatic bias adjustments and real-time calibration of the radar rainfall rates prior to product generation. This will improve product accuracy and utility still further and correct for estimate disparities. More recently, polarimetric studies have found that rainfall is well estimated from specific differential phase (Ryzhkov and Zrnic, 1996). Thus, these rainfall estimates and associated algorithms are expected to undergo substantial improvement with the coming addition of polarimetric capabilities to the WSR-88D.

In addition to providing invaluable data to forecasters responsible for issuing flash flood warnings, knowledge of aerial rainfall accumulation may be used to aid in preparation of main stem river stage forecasts. Improved estimates of runoff also may be used by reservoir tenders in order to manage releases and minimize downstream flooding while preventing dam topping. Over a longer period, the rainfall estimates may be used in soil moisture accounting models to aid in such activities as planning irrigation schedules and estimating crop production over large areas. Also this information will be used to improve hydroelectric power production and management as well as conservation and preservation of drinking water.

Any radar-based precipitation estimation is subject to contamination by ground clutter and anomalous propagation (AP). The WSR-88D/98D clutter suppression algorithm has been found to be quite effective in preserving returns from meteorological targets while suppressing non-meteorological echoes. The power density spectrum of the radar return relative to phase shift is examined and subjected to a notch width filter which attenuates that portion of the return with velocities very near zero. In fact, suppression capability has been measured to exceed 55 dB. Since most non-meteorological echoes are stationary, attenuation of the very low velocities effectively removes their contribution to the power returned. In nearly all cases, the notch width is sufficiently narrow that little attenuation of meteorological return occurs. However, in cases of stratiform rainfall, significant attenuation of meteorological returns may occur perpendicular to the mean

low level winds where radar measured velocities are essentially zero and subject to attenuation by the clutter filter. The net result is an underestimation of precipitation accumulation in a small region under the radar umbrella. The area affected is so small, it is normally compensated for by internal algorithm error checks and is interpolated across.

Stored as part of adaptation data at the RDA is a bit map of "normal" ground return, which is used to define those areas in which the clutter filter should be activated. The operator has the option of applying no clutter filtering, selecting only the predefined bit map for clutter filtering, or forcing clutter filtering over any area under the radar umbrella. This capability can be used for AP removal. Experience gained with practice will aid operators in selecting the correct clutter filtering strategy for each meteorological environment. Note that some changes, especially to point clutter suppression will be made when the desired radar targets are birds.

6. Convective Storm Applications

Perhaps the most mature and automated system application is that for the convective storm. As stated earlier, the majority of RPG algorithms (i.e., STI, Tornadic Vortex Signature [TVS], M, Hail Index [HI], VIL, SWA, CR, and Trends) are designed for convective storm diagnosis and especially the detection of severe convective storms. Additionally, the utility of STI, HI, M, and TVS is augmented by their use and scaling with background maps, and their availability as overlays on all other matching geographic products. Not only are many of the derived products designed for thunderstorm application, but the base products are also extremely important as well in checking the dependability, reliability and accuracy of the algorithm guidance. Both product types are considered here.

Virtually all convective storms begin as non-severe multicellular complexes that must be monitored for strengthening and development of potential severe weather. During the storm's entire life, the most valuable products are R, V, STI, VIL, and the HDA algorithm and related HI product, as well as either the OHP or STP precipitation products. Echo Tops are also of use here as are vertical cross-sections. The Reflectivity Cross Section (RCS) is also valuable in diagnosing vertical structure and storm type. For example, considerable research has resulted in a well-established model for the multicellular hail storm (e.g., Browning, 1978). Often, however, the quarter screen display is most valuable for revealing storm structure (Lemon et al, 1992) due to the great dependency of precisely placing the RCS axis. The forecaster uses a programmable macro called a "User Function" permitting, at a single mouse click, the display of four reflectivity products each at progressively higher elevation angles. With the quasi-horizontal nature of each slice, the change in storm structure with height is quickly apparent and many of the established three-dimensional severe weather signatures can be checked. With the use of background maps, the existence of Weak Echo Regions (WER), Bounded WERs (BWER), shift in echo top location, and the elevated extent of reflectivity maxima are easily discerned and location noted. All have been linked to storm potential severity (e.g., Chisholm and Rinick, 1972; Lemon,

1980; Burgess and Lemon, 1990). Velocity products to match the quarter screen reflectivity products permit simultaneous display of the storms kinematic structure with height via another User Function. Often, either this velocity quarter screen display or the Velocity Vertical Cross Section (VCS) are used to examine the storm summit outflow strength found to correlate very well with surface hail existence and size (Witt and Nelson, 1984). However, the same velocity products also permit detection of, at first, mid level cyclonic shear and then possible further development and downward progression of the mesocyclone (Burgess, 1982; Lemon and Doswell, 1979).

Additionally, a recently documented WSR-88D/98D signature dependent on radar wavelength and the Mie scattering characteristics of large hail has been documented by Lemon (1998). He calls the signature a "three-body scatter spike" (TBSS) but others have called it a "flare echo" or "hail spike". Lemon discusses the theoretical support for this signature and its association with large or very large hail and its use for hailstorm warning. He shows several TBSS examples obtained from recent WSR-88D archives and concludes that this signature is a sufficient but not necessary condition for large hail identification. It is stressed that when detected in mid-levels as is typical with hailstorms, those storms contain, with certainty, rapidly growing large hail. Because it is detected aloft and very often 10 to 30 minutes prior to large hail at the surface, it has short term predictive value. These same storms exhibiting the TBSS are often also very damaging wind producers.

The system automated alerting feature is of significant use here (as well as throughout the storm severity detection process). For example, the Mesocyclone product can be paired with alerts, such that with the automated detection of the mesocyclone by the algorithm, an audio/visual signal, User Alert Message, and a product centered (when appropriate to the requested product) on the alerting phenomena, are all automatically produced and sent to the requesting associated PUP.

The CR product and especially the associated Combined Attribute Table are effective as well. The image portion of the product displays the highest reflectivity within each Cartesian grid element found at any elevation angle in the volume. The table, included with only the CR product, lists for each identified storm, its location, whether it contains a TVS, a Mesocyclone, Hail probabilities, maximum expected hail size with the storm, the value and height of the maximum reflectivity, Cell Based VIL and the storm motion. Storm listings are ordered by storm severity, i.e., according to algorithm identified severe attributes.

Of course, the VWP product is important because the wind flow in the convective boundary layer is sampled permitting determination of streamwise storm relative vorticity and helicity (Davies-Jones 1984, Davies-Jones et al, 1990). These values indicate a storm's likelihood of acquiring a mesocyclone. As discussed previously, precipitation products are valuable owing to the importance of convective storms in flash flood production.

Finally, product manipulation is important as well. Products may be looped, recentered and magnified, filtered, and selected levels blinked. As previously addressed, they may

be displayed in quarter screen, singularly, and with a variety of overlays and background maps. Space does not permit further consideration here but the interested reader is referred to Lemon et al., 1992, and Ruthi et al., 1993, for details on operational application of the system and to Klazura and Imy, 1992 for further algorithm and product details.

7. Other Observations and Applications

We have described some of the more routine uses and capabilities for the WSR-88D system. Here we mention some of the less well-known observations and potential applications. However, these by no means comprise an exhaustive list but simply represent unfolding system potential.

The following include somewhat unique observations especially for an operational weather radar, reported and confirmed by those using the systems in tests or operationally:

- Smoke plumes from grass fires, even at long distances (greater than 200 km),
- Firework detonations and associated smoke plumes,
- Cold air funnel clouds (at less than 40 km),
- Birds leaving their nocturnal roosts from within nesting areas at sunrise,
- Bird and insect migration,
- Cloudless convective currents and streets,
- Rankine Combined eye-like vortical flow associated with a winter time extratropical storm center.
- Chaff/Precipitation discrimination

The following represent a few of the less well-known or realized system applications; but, as before, this is not an exhaustive list:

- Eventual automated identification, tracking, intensity measurement, and seawater storm surge prediction for hurricanes and typhoons,
- Enroute aviation hazard avoidance and fuel savings,
- Drift, trajectory, and dispersion of hazardous airborne pollutants or of aircraft-delivered materials, such as agricultural sprays.

8. Biological Target Detection And Applications

Of course, relative birds and flight safety in the Middle East , a prime concern is the WSR-88D/98Ds ability to detect, identify, and track biological targets, specifically birds. First, we consider a brief historical overview of radar bird detection capability as well as some recent bird observations by the WSR-88D. And second, the potential for bird-aircraft warning algorithms and potential future advances of such are considered. There will be redundancy with other papers within this volume but this will provide a context for how we got here, where we are now, and where we may be going in the use of the WSR-88D/98D for the above mentioned algorithms.

With the realization that radar can detect birds and its potential use in studying bird migrations and habits, progress has been made along these fronts, (Eastwood, 1967;

Gauthreaux, 1970; Richardson, 1979; Kerlinger, 1989; and Bruderer and Liechti, 1995). Generally developments were directed mostly at studying birds and bird migration with radar. However, in addition, work was carried out with the vision of the potential for bird-aircraft strike avoidance, (Larkin and Quine, 1989; Buurma and Bruderer, 1990; Government of Israel, 1995; and Leshem and Gauthreaux, 1996).

An excellent summery for radar application to bird strike avoidance is available which outlines areas such as the problem of aircraft encounters with birds, the radar potential for warning, radars considered, and potential of operational application (Buurma and Bruderer, 1990). But even before this time Larkin and Quine (1989) anticipated application of the next generation of weather radar for bird avoidance. That radar generation is now here, of course, as we have been considering at some length. These, the WSR-88D/98D are, without question, the best weather radars in the world today.

Early on the work of Larkin looked toward the application of the WSR-88D (NEXRAD) to the detection of various birds and under various conditions. He emphasized algorithms that would detect migrating waterfowl, widespread migrations, and bird roosts. However, during the period of his work, the WSR-88D was not yet available and he used research radar for development. Limitations of his approach include radar horizon, terrain masking, limited vertical radar resolution, and aspect ratio. Additionally, limitations include a software requirement to deal with large amounts of weather returns for a small number of bird targets. A new algorithm for each new class of bird is required, and a high resolution, which, in some cases, requires implementation of a "track while scan" approach. Advantages include algorithm development specifically for the best weather radars and technology available, a strictly software approach, and its application to the most dangerous of bird-aircraft threats, that of waterfowl and large scale migrations of large birds.

Another developing avenue has been designed by Sidney Gauthreaux, (Gauthreaux, 1994, and other publications). While strictly speaking, this technique is not yet an algorithm; it does hold some promise for future improvement and incorporation into an algorithm technique. The notable point in nearly all of his work is that he used strictly the WSR-88D.

A second and more recent and robust approach to an automated system specifically for bird avoidance is the "Avian Hazard Advisory System" or AHAS developed by Geo-Marine, Inc. Kelly describes that technique elsewhere in this volume and again it uses the WSR-88D. Current limitations of this approach include the same radar limitations mentioned above, its relatively long processing period, its current failure to include the first and second moments of the radar data (i.e., mean radial velocity data, and velocity spectrum width data), and its reliance on only commercially processed and grided data. Most of these limitations appear to be limitations that can be overcome. Advantages include a near-real time application, its use of the Larkin "widespread migrations" algorithm, and the use of the supporting Bird Avoidance Model (BAM). Moreover, ability to remove

weather data through the use of weather satellite imagery, weather model data, and surface weather observation data, and its inclusion of different time frames for the threat, such as a forecast component, are also advantages.

An obvious added advantage of both the Larkin, Gauthreaux, and especially the AHAS approaches are their design specifically for the use with the WSR-88D/98. These radars include the distinct advantages of the S-band weather radar for both bird detection (Zrnic and Ryzhkov, 1998) and meteorological applications (Lemon et. al., 1992, Lemon and Burgess, 1990; and Lemon, 1998).

Here we will site only a few of the many WSR-88D bird detection examples by U.S. forecasters from a variety of locations. We have already mentioned the "blooming" of the boundary layer reflectivity surrounding the radar at sunset at virtually all radar sites during the warmer months of the year. Reflectivities are often in the 0 dBZ to 15 dBZ range and will extend, at times, outward to over 150 km from the radar. As pointed out earlier, this is most often associated with locally roosting and feeding birds. However, not uncommonly and during certain months of the year, these echoes are migratory bird flights. This has proven to be a liability to the forecaster, especially when these echoes are from nocturnal migratory bird flights. These birds often "ride" the low-level jet, a very important low-level wind filed used for forecasting. Unless the forecaster understood the origin of this large region of echo, he may fail to notice that observed radar detected velocities will be 10 m s-1 to 15 m s-1 over that of the actual winds. This is especially true because the radar measures the power weighted mean velocities. In other words, it is the larger reflectors that dominate the radar measured velocities. Of course, those larger reflectors are the large birds. Moreover, at times the radar reflectivities are obviously higher along the radar azimuths normal to the bird orientation.

In another example, and common to nearly all radar locations, are the observations of expanding "donut" reflectivity rings at sunrise. The radar observer knows it is sunrise because the reflectivity radial "sun spike", power from the sun reaching the antenna, can be seen simultaneously with the emergence of the ring-echoes. Birds leaving their roosts with the first sunrays of dawn cause these echo rings. These rings have been observed by this author at times up to ~120 km from the radar.

In a final example mentioned here, Mexican Free Tail bats have been observed as they leave their caves at sunset at many locations. In one case observed by the author, an estimated 4.5 million bats could be readily detected by one WSR-88D located ~100 km from the bats. Reflectivities ranged from >45 dBZ above but near the cave mouth, decreasing within the expanding ring minutes later to 35 dBZ, and gradually falling off until the echo was no longer visible several tens of minutes later. Contemporaneously, these same bats were detected by a second WSR-88D located ~215 km from the cave. The reflectivities observed by this second WSR-88D were never greater than ~12 dBZ. It is believed that super refraction of the radar beam, especially from the distant radar, almost certainly aided in these observations.

The few above mentioned observations only serve to confirm the observations of Gauthreaux and others. Owing to many, many, other similar yet differing observations (see, e.g., Kelly, this volume), and from nearly all radar sites, the WSR-88D has proven to be a very capable tool for bird detection. Thus, without doubt, further development of the existing weather radar bird-avoidance algorithms should be pursued.

Future potential improvements for the chosen algorithm or combination of algorithms include application of velocity and velocity spectrum width data. These data appear to have some capability for discrimination between soaring or migrating birds, and bird type, and magnitude of the threat. These additional data will probably be implemented in the AHAS in the relatively near future.

While the WSR-88D/98D equipped with, for example, AHAS algorithm, will perform very well in helping to mitigate the loss of pilots and aircraft, it is only one, although a major advance toward that end. Plans and designs are being made for another major advance in the WSR-88D/98D radar's ability to perform yet an even further improvement in effective bird avoidance. That plan involves the relatively near term incorporation of polarimetry variables for the enhanced insect and bird detection and discrimination (Zrnic and Ryzhkov, 1998). When the upgrade is completed, the radar will alternately transmit horizontally and vertical polarized waves. The available and highly useful polarimetric variables are specifically: deferential phase, backscatter differential phase, and the correlation coefficient between the horizontally and vertical polarized data. Using these data from the 10-cm WSR-88D/98D, the insects backscatter predominantly in the Rayleigh regime, whereas the birds are mainly in the Mie range of sizes. Neither the differential reflectivity nor differential phase depends on the concentration of scatterers within the volume as does the equivalent reflectivity factor. Therefore combining these two measurements, will, with some degree of confidence, make it possible to roughly estimate the size of the bird targets. Incorporation of ploarimetric data appears to hold great promise (Zrnic and Ryzhkov, 1998). Thus, these data will probably hold the considerably enhanced capability to also discriminate insect from bird echo, and will also include some relatively direct information on the size and type of bird.

9. Operational Performance and Conclusions

The WSR-88D operational performance has exceeded all predictions. However, this is not to say that the system is functioning flawlessly. It is not. A few problems are being reported as is expected when new technology, especially computerized technology employing 400,000 to 500,000 source lines of original code, is introduced into operations.

Even after only one full year (1992) of NWS operational system application in Oklahoma, a severe weather prone region, statistics showed that the experience and knowledge of the warning forecaster when coupled with this exceptional tool could lead to some impressive results. After a total of 840 severe events and 1100 warnings issued, a Probability of

Detection (of the severe convective storm) of .95, a False Alarm Rate of .35, and an average lead time of 18 minutes for tornado warnings was achieved. All these values are better by at least a factor of two when compared to the national averages before the radar instillation. For the tornado warning, lead time was better by a factor of nine. A few other NWS offices reported warning performance that was even better than these. Nationally, a considerable improvement but somewhat less than those achieved in Oklahoma have been proven. What would have been rated as exceptional performances by yesterday's standards are common at all sites. At the Sterling, VA site, it was reported that in one instance the office very accurately predicted total snow accumulation, thereby preventing the closing of area Government offices as was advised by other conventional forecasts. This single event saved the Federal Government ~ $45 million U.S..

Presented here have been a variety of applications that are both realized and potential with this system. The WSR-88D is so superior and unlike any other operational weather radar that it can be characterized as a powerful remote sensing tool of a new kind, a new "window" on the atmosphere. It has been said that it is not uncommon for some, previously unobserved, atmospheric (or environmental) characteristic or phenomena, to be revealed during system use. Every remote sensing tool has been found to have a long learning curve, the WSR-88D/98D will be no exception but enough is now known and routinely found that this same learning period will be an extremely productive one as well. This is especially true with biological target detection. There appears to be a very great potential for improved bird-aircraft accident avoidance. With proper algorithm development and the addition of not only the other Doppler moments but also the eventual addition of polarimetry, performance of the WSR-88D/98D may actually exceed that for meteorological applications.

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Factors Affecting Bird Hazards in and Around Israeli Aerodromes

Yaron Weisbein and Eyal Shy
Science and Conservation Division,
Nature and National Parks Protection Authority,
78 Yirmeyahu St., Jerusalem 94467 Israel

Abstract

A combination of three major factors has led to Israel's unique situation wherein a large number (> 500) of bird species and dense populations of birds occur in and around Israeli aerodromes, thereby increasing BASH (Bird Air Strike Hazard). One is the location of the country where several zoogeographical regions meet, thereby generating a large variety of habitats suitable for birds. The second factor is that one of the world's main migration routes for birds (between Europe and Africa) passes through Israel. The third factor is the dense human population that has artificially enhanced the population growth of several bird species.

Attractions to large numbers of birds vary among aerodromes, but several major factors which significantly increase BASH can be identified. Natural and semi-natural fields within airfields attract many seed-eating birds such as pigeons and doves, chukar partridges, and seed-eating songbirds. Bare ground alongside the runways provides ideal conditions for ground-breeding birds, especially Spur-Winged Plovers and Stone Curlews. Garbage dumps within and close to airfields, attract large numbers of omnivorous birds, especially crows (all year round), and gulls (in winter). Water bodies such as oxidation pools, rain ponds, and drainage canals are common within airfields and are used by a variety of water birds, mainly during winter. Many airfields are surrounded by agricultural crops, especially seed bearing plants that attract birds.

The most effective guidelines the Nature and National Parks Protection Authority has given to the Airports Authority and the Air Force for reduction of BASH in aerodromes relates to the elimination or reduction of bird-attracting factors. This includes recommendations to use natural fields within airfields for agriculture but under strict control, including the choice of crops (no seeds) and the timing of planting and harvesting. We have also identified within each airfield other bird-attracting factors and have recommended their removal or concealment. Other recommendations for reducing bird hazards include the use of bird deterrents (distress and predator

calls, gas canons, pyrotechnics, etc.), bird trapping (special crow traps, pigeon traps and the like), and the controlled hunting of game birds (chukars and ducks). During the breeding season we put much effort into finding nests on the ground next to the runways and removing them.

Naturally, these techniques were most successful in those airfields which followed our recommendations carefully.

Introduction

The phenomenon of Bird Air Strike Hazard (BASH) is a worldwide problem that began with the commencement of air travel and has become increasingly serious with the continuing development of aircraft. As the speed of planes increased, the birds' ability to avoid them diminished. More and more collisions took place, some of which ended tragically. Fighter planes, by their nature, are at higher risk for bird collisions due to their high air speed plus their (sometimes) low altitude. The development of jet engines — which literally suck in air and with it, birds — further exacerbated the problem. The degree of damage is a direct outcome of the pressure to which the plane is subjected at the time of the collision with the bird (a function of the speed of the plane and the weight/mass of the bird). The problem is especially severe in the vicinity of airports, since planes circle at low altitudes during landing and take-off, in proximity to large concentrations of birds.

A combination of three major factors has led to Israel's unique situation whereby a large number (>500) of bird species and dense populations of birds are found in and around Israeli aerodromes, thereby increasing BASH. The first factor is location: the country sits astride the junction of several zoogeographical regions and, in consequence, is home to a large variety of habitats suitable for birds. The second factor is that one of the world's main bird migration routes (between Europe and Africa) passes through Israel. The third factor is a high human population density that has artificially enhanced the population growth of several bird species.

The enormous financial damage involved in bird-airplane crashes and, more telling, the growing number of victims, has prompted a search for ways to prevent these collisions, with guidance from experts at the Nature and National Parks Protection Authority.

Preventing Bird Strikes in Aerodromes

The following steps have been taken by the Nature and National Parks Protection Authority to give the best advice in order to prevent BASH:

1. Identifying bird presence and bird attracting factors in airfields.
2. Recommending ways to eliminate or reducing BASH.
3. Evaluation of carrying out recommendations in the field and revising them accordingly.

Factors Attracting Birds to Airfields

Avian food sources and eating habits vary at the different airfields and also change during the course of the year. Food leftovers and other organic garbage that litters aeordromes, along with food provided for guard dogs, attract very large numbers of crows (Corvus Corone).

Garbage dumps attract crows, Chukar Partridges (Alectoris chukar), pigeons, and many other species of birds. Pools, ponds, reservoirs, and drainage canals found at or near airfields also provide food, drinking water, and resting sites for many water birds and other species.

The year-round resident birds found at aerodromes (crows, pigeons, Chukar Partridges, Stone Curlews (Burhinus oedicnemus), Spur-winged Plovers (Hoplopterus spinosus) and others) find ample food there, together with very convenient conditions for breeding, hatching, and raising their chicks.

Crows nest at the tops of trees (mainly eucalyptus) found in abundance in and around airports. A relatively large bird, crows present a serious danger to planes when the birds cut across flight paths on their way to and from their feeding grounds.

Pigeons nest in trees, in airplane sheds, in buildings, and especially in hangars where their droppings cause serious damage to the body of the plane. Sometimes the pigeons themselves or their nesting materials are even sucked into an aircraft's motor on ignition, again causing significant damage.

Partridges lay their eggs on the ground in thickets and drainage canals, near flight paths or between them, away from areas frequented by people where the nests will not be disturbed. Partridges fly low and hence endanger planes primarily during take-off and landing.

Spur-winged Plovers and Stone Curlews are also ground-breeders but they prefer to nest in open areas, mainly on bare ground alongside runways which provide excellent camouflage for their eggs. These are laid generally in a small indentation in the ground or sometimes even right on the surface, buffered round about by small stones. On runway verges there is almost no human traffic, so there is no one to disturb their nesting, laying, and raising of the chicks (the movement of planes taking off and landing does not bother them). Like partridges, curlews, and plovers present a danger to airplanes mainly during take-off and landing. The Stone Curlew, a nocturnal bird, also threatens night flights.

The birds find places to hide from predators, in resting and sleeping places in the underbrush along the margins of runways and in agricultural fields between them, in drainage canals that run alongside them, in dumping sites, hangars, and abandoned buildings all over aerodromes, as well as in trees on the airfield grounds and in the near vicinity.

The birds' rapid adaptation and their almost complete indifference to the noise of the aircraft, the isolation of aerodromes from potential predators, as well as the ample plant life, water, and food — all these create exceptionally comfortable conditions inviting long sojourns.

Methods for Keeping Birds Away from Aerodromes

The most effective guidelines the Nature and National Parks Protection Authority has given to the Airports Authority and the Air Force for reducing BASH in aerodromes relates to the elimination or reduction of bird-attracting factors.

We have suggested preventing the dumping of organic garbage in dumps sites at aerodromes, and transporting it instead to properly equipped regional dumps and, insofar as possible, doing the same with construction wastes, discarded metals, and trash of all kinds. When organic garbage has to be located in or near an aerodrome, it must be covered with soil, and deterrence methods should be employed to keep birds away.

Another of our recommendations has been to eliminate winter rain ponds and any other standing water near flight paths. In the event that this cannot be done for some reason, deterrents (gas cannons, explosive pistols, etc.) should be located nearby to discourage birds attracted to the site.

Weeds that grow in the cultivated areas and alongside runways must be sprayed, since they provide hiding and nesting places for ground-breeding birds. Spraying is also required to eliminate the weeds that grow in and around standing pools of water and attract waterbirds and songbirds.

Natural fields within aerodrome perimeters may be used for agriculture, but only under strict control, including the choice of crops (preferably those which do not produce seeds) and the timing of planting and harvesting.

Since one cannot entirely eliminate the factors that attract birds to aerodromes, our recommendations include minimizing the threat by employing techniques to deter, repel, remove, and reduce the number of birds that are resident in aerodromes.

High-quality recordings of bird distress calls signifying stress, distress, and fear, as well as recordings of predator calls can be used to repel certain species to the point where they disappear completely from the area or stay away for a while. Alternatively, one may also use artificial electronic imitation of distress calls.

A special pistol firing noise explosives accompanied by flashing lights, will frighten birds away from a limited area during a specific time. This method should be used in a controlled manner, since overuse will reduce its impact on the birds. Likewise gas cannons may be used, mainly against flocks and concentrations of birds; these produe explosive sounds in a specified or a variable direction after each firing. Their impact is limited (an effective range of about 250 meters) and they must be used in a controlled manner and only as needed, not continually. Their position should be changed frequently to prevent habituation by the birds.

Additional means to deter and expel birds include figures of birds of prey painted in repulsive colors and flapping in the wind; bird carcasses or stuffed birds scattered in conspicuous, high-visibility places to deter and frighten other birds of the same kind; radio-controlled model planes or drones to expel large concentrations and flocks of birds.

Against bird species habituated to, or less affected by these techniques, the following steps may be taken:

To reduce the numbers of such species, we dispatch licensed hunters to selected aerodromes, with proper permits for hunting at aerodrome sites. Bird species hunted at aerodromes are mostly game birds and overpopulated species (Hooded Crows, pigeons, Chukar Partridges, and certain species of ducks during the winter). The hunters must thereafter turn over the contents of the birds' gizzards; when analyzed, this information enables us to learn which food the birds prefer. Then, we advise farmers to refrain from cultivating those crops within or near aerodromes.

Crows and pigeons are continually caught through the use of designated traps, and then removed from the aerodrome on an ongoing basis. This activity must be pursued on a regular schedule because the space vacated in this manner very quickly fills with new birds.

We provide guidelines and instruction on how to locate camouflaged nests of ground-breeders like the Stone Curlew or Spur-winged Plover along the margins of runways. A nest, once identified, facilitates rapid capture of the parents using simple traps laid on the eggs (exploiting the maternal instinct to return to the eggs), and the removal of the birds from the airfield. Relocating them at a distance of more than 50 km from the airfield should prevent their return in future to nest in the same place. Another option we have been trying recently is to spray the eggs in the nests with paraffin oil. Embryo development is interrupted, while the female continues sitting until the end of the nesting season (between March and August). If the nest is abandoned and another is built, this too is relocated and the process is repeated. Chicks caught are removed to one of several registered local zoos or to a zoological garden at a university.

Naturally, these techniques have been most successful in the airfields where our recommendations have been carefully followed.

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Pigeon And Crow Population Control by Trapping

Ben (Ze'ev) Foux
Forest Ecological Solutions Co., Ltd, P.O.Box 23355 Tel Aviv, Israel 61231

Abstract:

Feral pigeons (Columba Livia) are a safety problem all around the airdrome, as they fly in big, dense flocks crossing the runways. Pigeons are also one of the worst foreign object damages in the hangars and are environmental and health hazards. Hooded crow is found around runways in Israeli air-bases, due to the thick vegetation that can be found in the bases.

Other methods for bird population control in use now are either repulsing (glue, spikes, nets) or eliminating (poison, shooting).

Trapping is an environmental-friendly, cost-effective long-term solution, with a history of thousands of years.Trapping is environmental friendly, cost-effective long term solution, with a history of thousands of years.

Forest Ecological Solution is implementing a trapping method which is based on three pillars: Ornithological knowledge about the bird; patented mechanical traps (Ecotraps®); environmental understanding.Forest Ecological Solution is implementing a trapping method which is based on three pillars : Ornithological knowledge about the bird; Patented mechanical traps (Ecotraps®); Environmental understanding.

The success of Ecotraps has been proven in different climates and geographical areas for over six years, with the excellent results of first year drop of 95% and maintaining low population level, for as long as the trap is in use.

Main Topics : Pigeons, crows, trapping.

Pigeons:

1. Background

Feral pigeon (Columba Livia) is a bird that thrives in man close vicinity. As such, they can be found in most man-made structures and environments. Any airdrome, with its big hangars and the absence of natural predators, attracts pigeons as a safe nesting and resting areas.

This is the reason that we can see pigeons, mainly in the morning and in the evening, crossing the runways in dense flocks and posing a direct safety risk. However, the risk is not limited to the runways. We find pigeons in hangars, digesting at night and leaving the airplanes and equipment below covered with their highly acidic secretion. Pigeons drops can penetrate through the paint and some of the alloys in use, harming expensive equipment and endangering human lives.

In addition, pigeons may carry up to 22 different parasites that can be transferred to

men by direct contact with the dead animal or by contact with its feathers or secretions.

2. The Ratio

Many companies and bodies in the world deal with pigeons overpopulation in many different ways. Generally, we can divide these methods into two main options. The first is repulsing the birds and the second is by population control.

Repulsing the bird is an expensive procedure in which we apply glue or spikes to thousands of meters of potential bird resting areas, and maintain those devices. We can also try to seal the structure with nets to use one of the new electronic- ultrasonic machines. According to our 15 years experience, as well as to our customers feedback, these methods are very costly not effective.

The other option, population control, can be done by shooting, poisoning or trapping. Shooting may cause three problems : A) Damage to structure and equipment. B) The

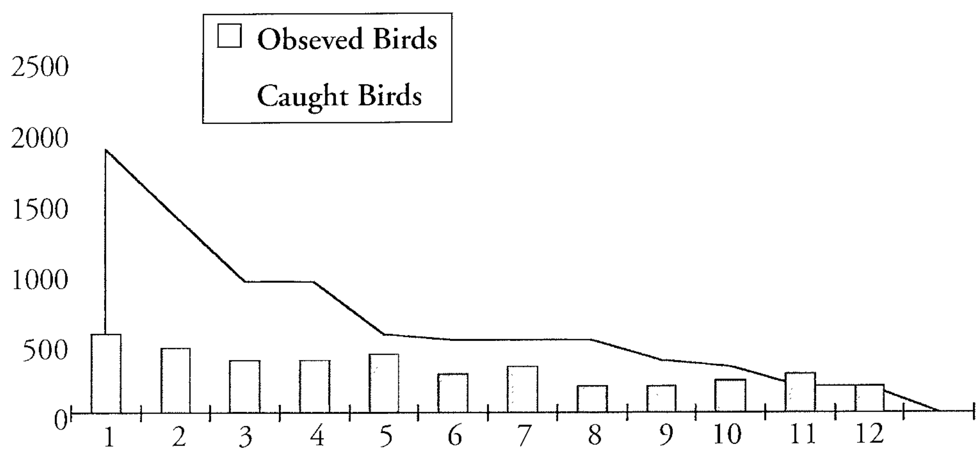
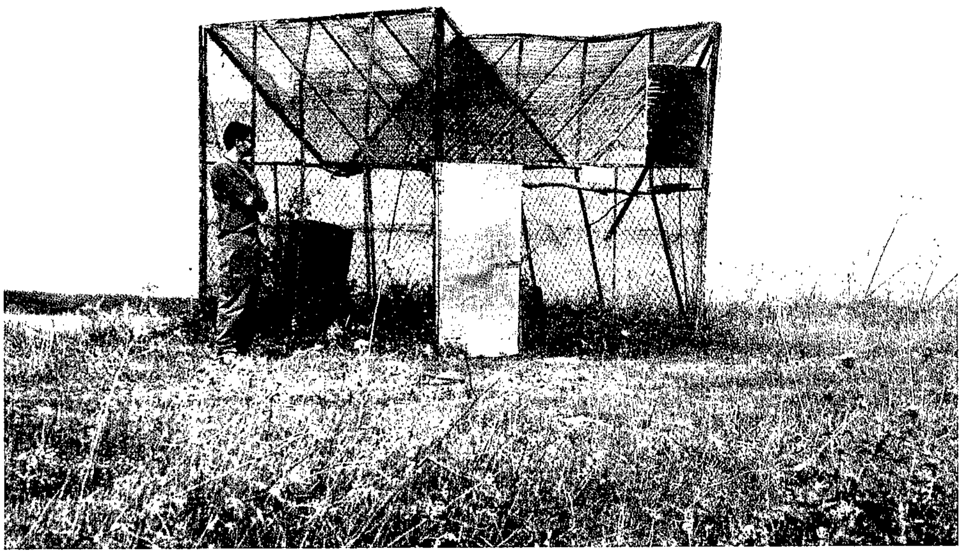


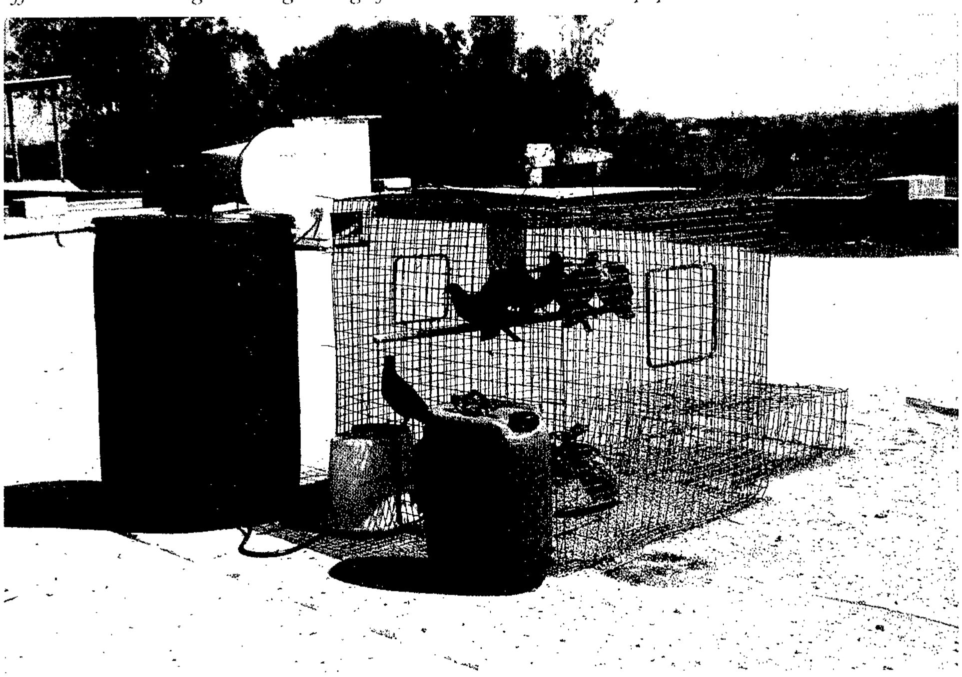
Figure 1: *Before Treatment*

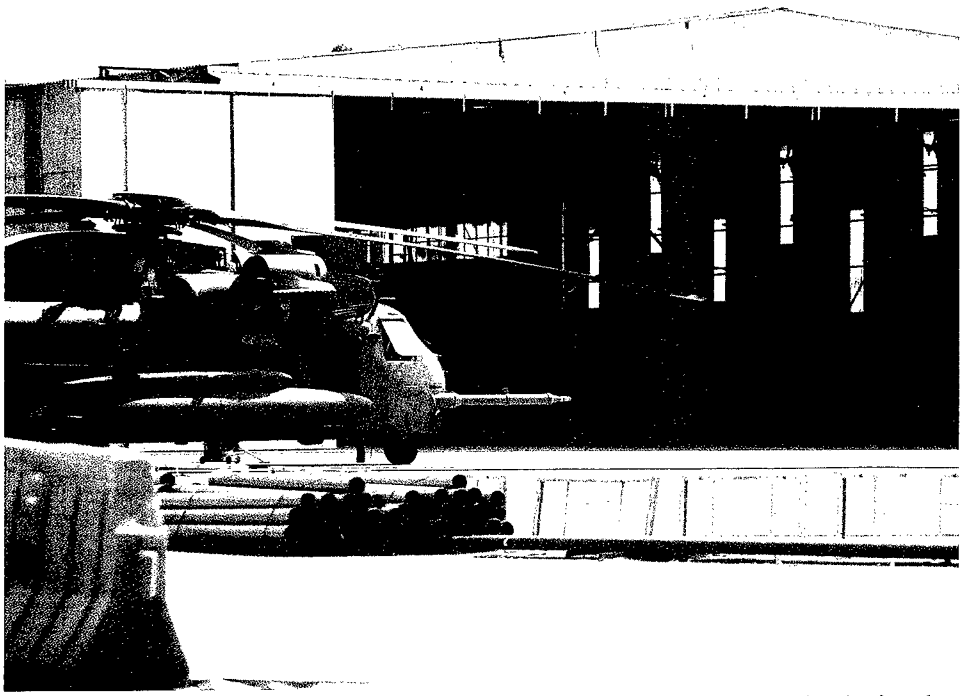
Figure 2: *After treatment*



Above: *"Forest" pigeon trap (patented 1994). A mechanical pigeons trap. Combined with correct environmental knowledge, it is responsible for more than 96% drop of feral pigeons in Israel aerodromes and other sites.*

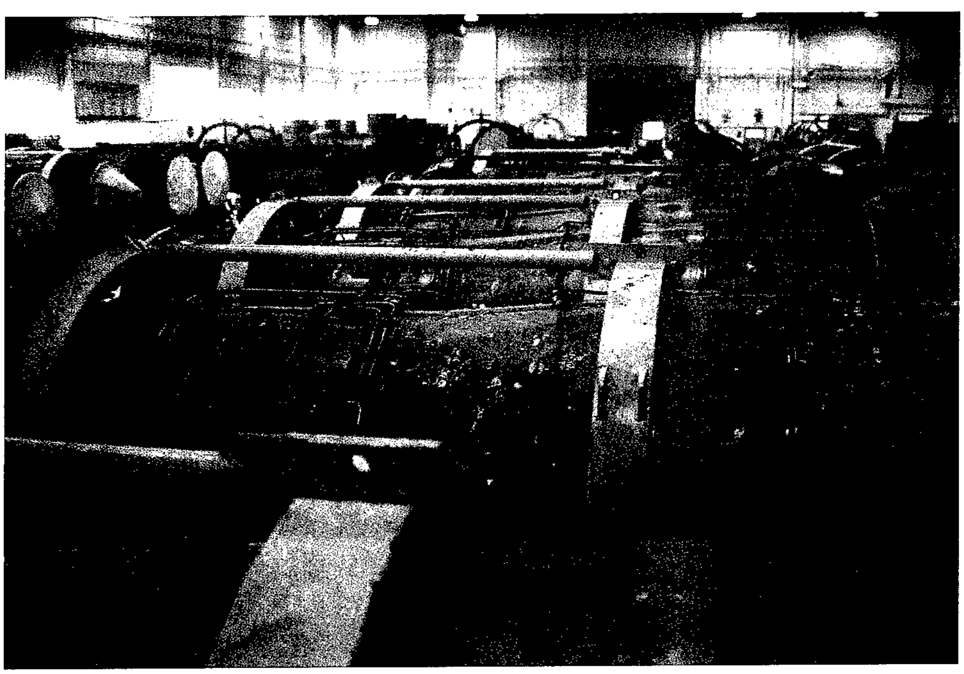
Below: *"Forest's" modified crow trap. This walk-in trap, based on the Australian crow trap, is extremely efficient in handling the out growing of the Israeli Hooded Crow population.*





Above: *Military (CH 53) hangar. Even military hangars, which are much smaller than civilian ones, are the preferred breeding and nesting sites for feral pigeons in aerodromes.*

Below: *Long-time storage hangar. Jet (F-15) engines, can suffer serious and costly damage from pigeons acidic secretions. The photo describes the situation at the beginning of "forest" operation.*



pigeon population is indeed effected by shooting but it rises again after a month or two as new flocks come to use this niche. C) leaving dead birds on the ground . Furthermore, most military air-bases are not allowed to use this method.
Poisoning creates a serious environmental problem, as the entire domain, as well as other animals, can be affected by the toxic substance used. It is against our principles to use this method, and actually, it is illegal in most countries.
As we observe the bird's habits and life cycle, as well as other methods in use now, we can see that solution to pigeon over-population should have the following characteristics : Pondering the whole domain, eliminating only the specific birds (not repulsing them), environmentally friendly, long-term, cost effective.

Trapping is the only solution that answers all of the above.

3. The Method

FOREST Ecological Solution Ltd. came up with the best solution - a sophisticated ecological trapping.
We took the ancient method of trapping and combined it with the most recent ornithological and ecological knowledge. We have conducted eight years of research and field tests before we started to use them commercially, six years ago. Ever since then, we are constantly improving the mechanical device, thus reducing the maintenance to a minimum.
The refined traps are elaborately places in key positions that were selected after serious observation. Each trap attracts pigeons from an area of over 30,000 square meters. One trap can sustain hundreds of birds for about three weeks, so that maintenance can be minimized.
Even though the traps have became more sophisticated, the method has remained the same. The method is based on patterns of bird behavior over time and in the whole terrain. We consider all ecological elements within the birds normal radius when we choose where to place the traps and who to attract to them. This attitude towards the fine environmental circumstances throughout time is the main factor in our excellent results.

4. Results

Based on experience from Israel International Airport, as well as from all major military airports, the average results figures are shown below.

	Observed Birds	%	Captured birds
At beginning	1250	100.00%	
After six months	500	40.00%	1500
After one year	90	6.40%	1000
After two years	20	1.60%	500
After five years	20	1.60%	300

Note the big difference between the numberes of observed and captured birds - there is a constant influx of new pigeon into the domain.
The airports mentioned are located all over Israel, with very different climates, landscapes and agricultural environment. Obviously, some of the devices and ingredients were adopted to the variations of the environment, but the principle is the same.
1. First year drop of 95% (!) in pigeon population.

2. Maintaining these low figures for as long as the trap is in place.

5. Points of Consideration

Even though pigeon is one of the birds to cause bird strikes most frequent, not to mention F.O.D. (Foreign Object Damage), they are mostly considered as a maintenance problem in hangars. Trapping solution is saving maintenance labor and costs. Nevertheless, eliminating this problem in the hangars has many benefits, such as creating a more safety environment and eliminating environmental hazard.
For these reasons, it is best if the whole airport is organized as a whole to solve the problem. This approach, that is common to military bases, has two benefits:
1. Reducing maintenance and cost of this solution.
2. The bird population is reduced in the whole territory, and is thus more effective.

Crows

1. The Problem

The hooded crow () is of the most common species of birds that live in men's close vicinity, especially in the Middle East.
Most of the Israeli air-bases are covered with thick vegetation and high trees, mainly eucalyptus, for camouflage reasons. The hooded crow nestes on these trees. Crows also feed on dog food, which is given to the hundreds of guard-dogs in each base. In this perfect environment of high trees and plenty of food, Hooded Crows have become a noticeable bird in the base.
Even though there is almost no evidence of collision with crows, maybe due to their high intelligence, they are considered a safety risk. Due to the big increase in crows numbers, as of this year Forest Ecological Solutions Ltd. was asked to try to solve this problem.

2. The Solution

As in the pigeon case, we are using a live trap that attract the crows by both bates and behavior patterns. The mechanical traps have been modified by Forest Ecological Solutions Ltd. to keep low level of maintenance and high attraction levels.

3. The Results

1999 is the first year in which these Crow traps were operated, thus we do not have

any statistics that can be analyzed. However, during these few months of activity we have came to the following conclusions:

1. The traps trap crows in big numbers.
2. Despite our efforts and guiding, there is still the problem of the availability of big quantities of dog food in the base.
3. Maintenance of the trap is damaged by "nature loving " personnael of the bases that sometimes destroy the traps and release all birds.

4. Points of Consideration

As mentioned above, the two main problems for reducing the crows population are reducing the access to food and stoping base personal from jeopardizing the tapping. Since the crow traps must be placed on the ground, and guard dogs must still be present in big numbers in the base, educating the staff is the only way for this solution to work.
The mechanical devices and the trap concept are proving to be very effective, judging from the high numbers of birds caught.

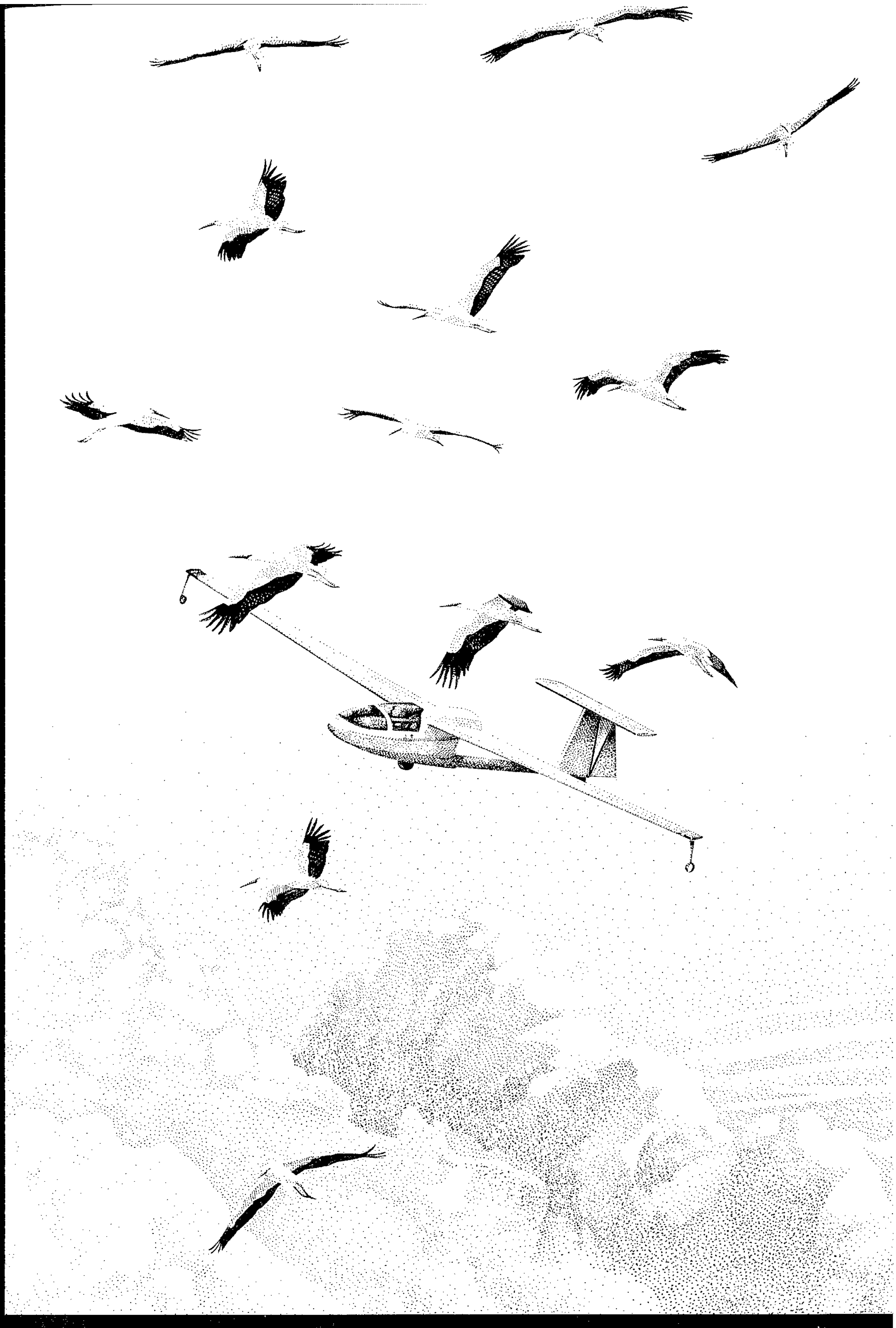
Summary

1. Sophisticated trapping is the best way to deal with pigeon and crows over population.

2. The airport should be considered as a whole domain.

3. The saving on the maintenance and environment control should be taken into consideration.

4. Cooperation from all air base personnel is necessary.

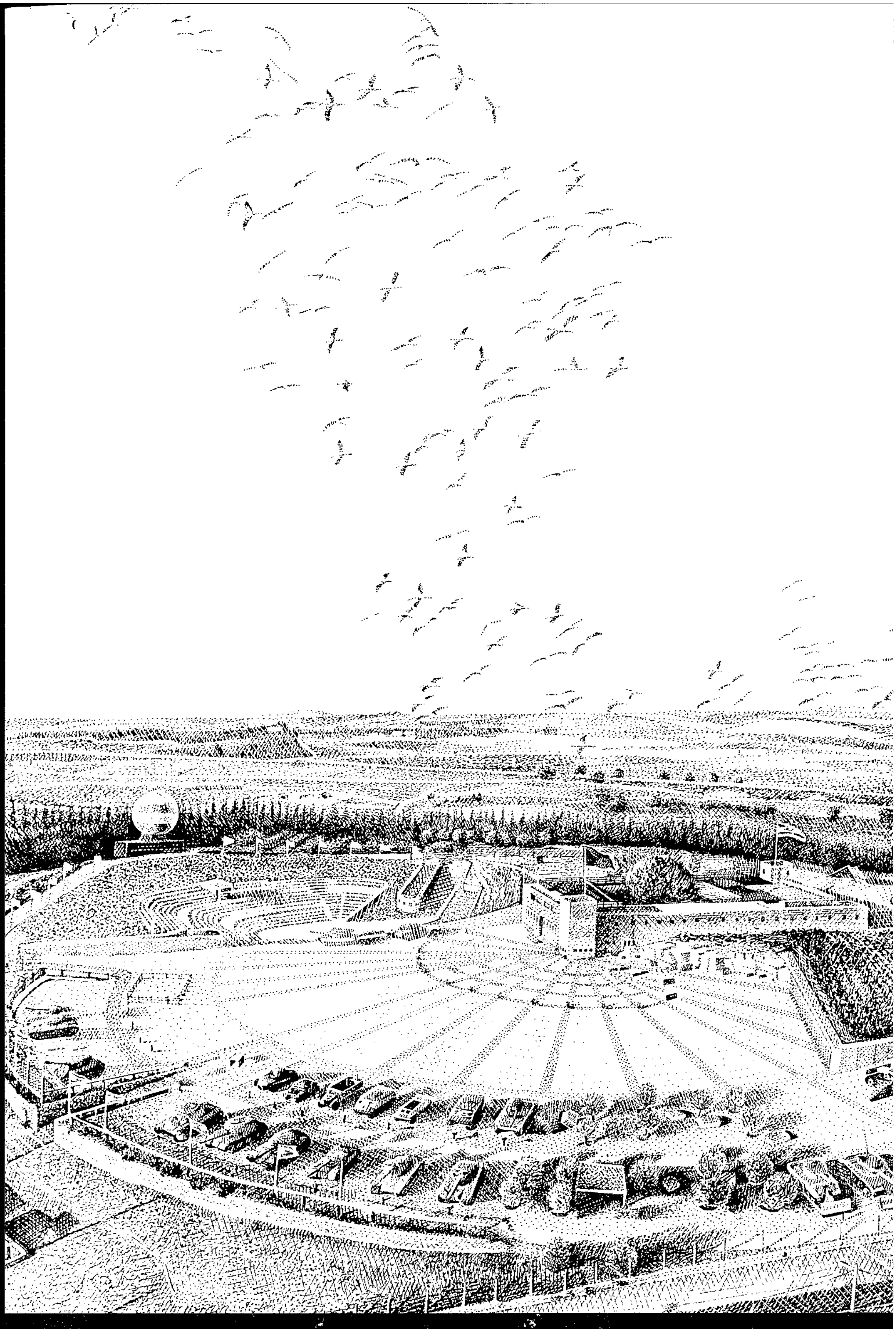


Summary of the International Seminar on Birds and Flight Safety in the Middle East
Working Plan Recommendations

This document is based on the summary of the International Seminar on birds and Flight Safety in the Middle East, April 25-29, 1999.

1) Establishing a joint working group in the Middle East.
   The working group will be lead by air force representatives from each of the participating countries and will be backed by each national academic and/or nature conservation organization. Countries that did not participate in the are always welcome to join.
2) Working group structure
   Elect a working group chairman, air force and academic/nature conservation representatives from each country, defining schedule of meetings, meeting locations and meeting content (it is proposed to schedule the first meeting for November, 1999 in Turkey).
3) International Bird Strike Committee (IBSC)
   Air Forces from each country are invited to send a representative to the International Bird Strike Committee (IBSC) meetings held every two years. The next IBSC meeting is being held April 17 — 21, 2000 in Amsterdam.
4) **Issues to be Promoted Through Regional Cooperation**
   a) Joint migration research through developing a regional ground survey network.
   b) Joint migration research by developing joint motorized glider flights.
   c) Joint migration research through satellite telemetry tracking.
   d) Joint migration research by developing a bird and weather radar network on one common system platform and one integrated information system (BAM — Bird Avoidance Model).
   e) Developing a regional real time warning system based on results from research projects mentioned in sections 4.a-4.d.
   f) Establishing a laboratory for feather remains identification in each country (based on the knowledge obtained through the joint project between the Royal Netherlands and Israel Air Forces).
   g) Improving bird hazard control on military bases
   h) Creating a working plan to ensure that the issues discussed will become operational in each air force.
   i) Additional issues that will arise during discussions
   j) Promote cooperation with the United States Air Force as well as other air forces active in the region that might be interested in joining this initiative.

This draft was prepared by the Israel Air Force, as a basis for the first meeting of the new joint working group for the Middle East. The IAF has proposed that Dr. Yossi Leshem will be the first working chairman. Future chairmen will be elected by the working group periodically, as decided in the first meeting.



List of Participants

(According to country, then alphabetical order)

CANADA	**GERMANY**
Mr. Bruce MacKinnon Aerodrome Safety Branch Transport Canada & Chairman, IBSC Public Relations Working Group Transport Canada Safety and Security 330 Sparks St. Place de ville-Tower C Ottawa, Ontario, KIA ON8, Canada Tel: 1-613-9900515, Fax: 1-613-9900508 E mail: mackinb@tc.gc.ca	**Mrs. Hiltrud Oberwelland** President of the Stork Foundation Waldstrasse 27 D-13403 Berlin Germany Tel: +49-30-41773315 Fax:+49-30-41773343
GREECE	**GREECE**
Maj. Gen. D. Athanassakos Inspector General Hellenic Air Force General Staff Messologion St. 15551 Athens, Greece Tel: +301-6527680, Fax: +301-6463276 E mail: webmaster@hafi.gr	**Lt. Col. D. Antoniou** Safe Flight Staff Officer Hellenic Air Force General Staff Messologion St. 15551 Athens, Greece Tel: +301-6524549, Fax: +301-6463276 E mail: webmaster@hafi.gr
ISRAEL	**ISRAEL**
Prof. Yair Aharonowitz Dean for Research Tel Aviv University Ramat Aviv, Tel Aviv 69978 Israel Tel: +972-3-6408475/7082 Fax: +962-3-6412170 E mail:yaira@ccsg.tau.ac.il	**Mr. Dan Alon** Director of the Israel Ornithological Center, SPNI Atidim Industrial Park P.O.B. 58020 Tel Aviv, 61580 Israel Tel: +972-3-6449622 Fax: +972-3-6449625 E mail: ioc@netvision.net.il
Dr. Ofer Bahat Head of the Griffon Vulture Program Kibbutz Ha'on 15170 Israel Tel: +972-50-969565 (mobile) Tel: +972-6-6656513 (home) Fax: +972-6-6709316 E mail: bahat@shani.net	**Maj. Gen. Eitan Ben-Eliahu** Commander Israel Air Force I.A.F., P.O.Box 02704, IDF, Israel Tel: +972-3-6942000/4/5
Col. Benny Cohen Head of Command of Control Units Headquarters, I.A.F. Tel: +972-3-6943020	**Lt. Col. Raanan Cohen** Head of Air Trafic Control Branch I.A.F. Tel: +972-3-69430240

Mr. Ilan Eilat
Managing Director Shaked Technologies L.M. (1995) Ltd.
Consultant to Lockheed Martin Overseas Corporation
Kiryat Weizmann Science Park , Bldg. 13A, P.O.B. 2486
Rehovot 76124, Israel
Tel: +972-8-9301393
Fax: +972-8-9301493
E mail: shakilan@netvision.net.il

Mr. Adiv Gal
International Center for the Study of Bird Migration at Latrun
Department of Zoology, Tel Aviv University, Ramat Aviv, Tel Aviv 69978 Israel
Tel/Fax: +972-3-6406010 (work)
Tel: +972-8-9421677 (home)
e-mail: selagal@trendline.co.il

Maj. Tal Gal
Foreign Affairs
I.A.F.
Tel: +972-3-6943551

Mr. David Glasner
Director of the International Birdwatching Centre
Jordan Valley, Kfar Ruppin 10850 Israel
Tel: +972-6-6068396
Fax: +972-6-6480612
E mail: dglasner@kfar-ruppin.org.il

Aby Har-Even
General Director Israel Space Agency
26a Chaim Levanon St., P.O.B. 17185
Tel Aviv 61171 Israel
Tel: +972-3-6422297
Fax: +972-3-6422298

Brig. Gen. (Ret.) Menashe Inbar
General Manager of the Armoured Corps Association
The Memorial Center and Museum– Latrun, Doar Na Shimshon 99762
Tel: +972-8-255268
Fax: +972-8-255186

Brig. Gen. (Ret.) David Ivri
Chairman of the Council for National Security
Tel: +972-3-6977775

Mr. Avi Kostelitz
Director General, Israel Airport Authority
P.O.B. 137, Ben Gurion International Airport 70100 Israel
Tel: +972-3-9710575/6
Fax: +972-3-9721722

Dr. Yossi Leshem
Director of the International Center for the Study of Bird Migration at Latrun
Tel Aviv University & SPNI
Department of Zoology
Tel Aviv University, Tel Aviv 69978Israel
Tel: +972-3-6407963 (work)
Tel/Fax: +972-3-6406010
Tel: +972-50-237087 (mobile)
Tel/Fax: +972-2-9932629 (home)
E mail: yleshem@post.tau.ac.il

Ms. Yael Mandelik
Israel Ornithological Center, SPNI
Atidim Industrial Park P.O.B. 58020
Tel Aviv, 61580 Israel
Tel: +972-3-6449622 (work)
Tel: +972-53-689680 (mobile)
Fax: +972-3-6449625

Mr. Yuval Milo
General Manager
FOREST Ecological Solutions ltd
P.O.B 23355, Tel Aviv 61231, Israel
Tel: +972-8-8692752
Fax: +972-8-8692753

Maj. Gen. (Ret.) Moshe (Mosa) Peled
Chairman of the Board Armored
Corps Association
The Memorial Center and Museum–
Latrun, Doar Na Shimshon 99762
Tel: +972-8-255268
Fax: +972-8-255186

M.K. Shimon Peres
President of the Peres Center for Peace
2 Hashalom Rd.,
Tel Aviv 67892 Israel
Tel: +972-3-5680680/1
Fax: +972-3-5627265

Dr. Miri Rosenboim
Kfar Nofah 73170, Israel
Tel: + 972-3-9329719
Fax: +972-3-9330924
E-mail: romi@mofet.maam98.ac.il

Col. Tamir
Head of S.A.F.I.D. I.A.F.
Tel: +972-3-6942370/1

Ms. Judy Shamoun-Baranes
Feather identification specialist, Tel Aviv
University & SPNI
Department of Zoology
Tel Aviv University
Ramat Aviv, Tel Aviv 69978 Israel
Tel: +972-3-64499622
Fax: +972-3-64499625
E mail: shamoun@post.tau.ac.il

Mr. Uri Orlev
Head of Safety Unit, Israel
Airport Authority
P.O.B. 137, Ben Gurion International
Airport 70100 Israel
Tel: +972-3-9710146
Fax: +972-3-9731650

Lt. Col. Alon Pereg
Head of International Affairs for the
I.A.F.
Tel: +972-3-6942026

Dr. Avi Perevolotsky
Chief Scientist,
Nature and National Parks Protection
Authority
78 Yirmeyahu St., Jerusalem 94467
Tel: +972-2-5005421
Fax: +972-2-5704241

Ms. Yael Shaltieli
Mayor Beit Shean Regional Council
Israel
Tel: +972-6-6065851
Fax: +972-6-6065862

Dr. Eyal Shy
Nature and National Parks
Protection Authority
78 Yirmeyahu St. Jerusalem 94467
Tel: +972-2-5005421
Fax: +972-2-5704241
E mail: eyalshy@cc.huji.ac.il

Dr. Shimshon Shoshani
Chairman of the board, SPNI;
Director General of the Jewish Agency
for Israel
P.O.B. 92 Jerusalem 91000 Israel
Tel: +972-2-6202086
Fax: +972-2-6202712

Maj. Gen. Gideon Shefer Vice President of the Air Force Association Sde Dov 48276 Tel Aviv 61480 Tel: +972-3-6907900/1	**Mr. Aharon Vardi** Director General of the Nature and National Parks Protection Authority 78 Yirmeyahu St., Jerusalem 94467 Tel: +972-2-5005403 Fax: +972-2-5374887
Prof. Yoram Yom-Tov Department of Zoology, Tel Aviv University Ramat Aviv, Tel Aviv 69978 Israel Tel: +972-3-6409058 Fax: +972-3-6409403 E mail: yomtov@post.tau.ac.il	**Lt. Col. Eric Weisman** Commanding Officer of Flight Safety Branch I.A.F. Tel: +973-3-6943042
JORDAN	**JORDAN**
Col. Pilot Malik Salamah Habashneh Head of Flight Safety Unit Royal Jordanian Air Force Safety Center	**Maj. Pilot Faisal Adnan Ebrahim** Royal Jordanian Air Force
Maj. Pilot Ziad Awad Ebrahim Royal Jordanian Air Force **Capt. Abedel Ra'uf Al-Dalabeeh** Military Liaison Officer	**Maj. Pilot Haitham Yossef Sa'ad** Royal Jordanian Air Force
Mr. Adnan Budieri Head of Middle East Division Bird Life International, Royal Society for the Conservation of Nature, P.O. Box 6354, Amman 11183 Jordan Tel: +962-6-837931/2 Fax: +962-6-847411 E mail: birdlife@nol.com.jo	**Mr. Khaled Irani** General Director of the Royal Society for the Conservation of Nature (RSCN) P.O. Box 6354, Amman 11183 Jordan Fax: +962-65347411 E mail: irani@rscn.org.jo
THE NETHERLANDS	**SWITZERLAND**
Dr. Luit Buurma Chairman of the IBSC, Royal Netherlands Air Force Chief Biologist Royal Netherlands Air Force P.O. Box 20703, The Hague 2500 ES Netherlands Tel: +31-70-349-2348 Fax: +31-70-349-2347 E mail: e.buurma@consunet.il	**Prof. Bruno Bruderer** Chairman of the IBSC Remote Sensing Working Group Swiss Ornithological Institute CH-6204 Sempach Switzerland Tel: +41-41-462-9700 Fax: +41-41-462-9710 E mail: brudererb@orninst.ch

TURKEY	**TURKEY**
Dr. Can Bilgin President, Turkish Bird Research Society (KAD) Associate Professor Department of Biology Middle East Technical University 06531 Ankara, Turkey Tel: +90-312-210-5017 Fax: +90-312-210-1289 E-mail: cbilgin@rorqual.cc.metu.edu.tr	**Brig. Gen. Murat Bulgan** Base Commander & Representative for the Turkish Air Force Command 9 Ana Jet Us K., 8 Alikesir, Turk Tel: +90-266-2459200 Fax: +90-266-2438846
Lt. Tuna Donmez Representative of the Flight Safety of the 2nd Tactical Air Command 7 Ana Jet Us 171. Filo K.liqi Malatya, Turkey Tel: +90-542-4129680 Fax: +90-422-3248169	**Lt. Col. Nuh Erdogru** Chairman of the Board of the Flight Safety 2 Ana Jet Us/Uc Eqt.Mrk.K.Liql.Uq.Emn.Ok.K. wdi/izmie Turkey Tel: +90-232-8333538 Fax: +90-232-3761427
Lt. Col. Yilmaz Goksen Military Air Attache The Embassy of the Republic of Turkey 202 Hayarkon St. Tel Aviv Israel Tel: +972-3-5241288 Fax: +972-3-5228562	**Cap. Muzaffer Kauci** Hv.K.K Dep.ve.Dest.Bsklipi Ua.Emn.Fb. Cankaya/Ankara, Turkey Tel: +90-312-2407304 Fax: +90-31204142627 E mail: flyman@artemis.efes.net
UNITED KINGDOM	**ISRAEL**
Mr. John Thorpe Honorary Chairman of the IBSC Brackens Chapel Road Smallfield Surrey, RH6 9JH UK Tel: +44-1-293-573225 Fax: +44-1-293-573999 E mail: john.thrope@srg.caa.co.uk	**Mr. Amir Balaban** Director of the Jerusalem Bird Observatory Itamar Ben-Ari 6 Nes Tziona 70400, Israel Tel: +972-8-9406157 Tel: 972-52-448879 (mobile) Fax: +972-8-9400850
USA	**USA**
Mrs. Lorraine Bolsinger Vice President, Military Market, Development & Transport, GE Aircraft Engine, One Neumann Way MD H328, Cincinnati, OH 45215 USA Tel: +1-513-243-3686 Fax: +1-513-243-7464	**Lt. Col. Dr. Russell Defusco** HQ USAFA/DFB US Air Force Academy CO 80919 USA Tel: +719-472-4175 Fax: +719-472-2420 E mail: defuscorp.dfb.usafa@usafa.af.mil

Dr. Richard Dolbeer US Department of Agriculture, APHIS Animal Damage Control 6100 Columbus Avenue Sandusky , Ohio 44870 USA Tel: +1-419-625-0242 Fax: +1-419-625-8465 E mail: mwrscandusky@lrbcg.com	**Mr. Robert H. Griswold** General Manager Military Engine Programs Department GE Aircraft Engines One Neumann Way, M/D H-346 Cincinnati, OH 45215 1988 Tel: +1 513-243-1322 Fax: +1 513-243-5000
Maj. Gerald Harris US Air Force Europe, Chief of Safety, Plans and Programs Division Unit 3050, Box 165 Bldg. 307 Rm. 2, APO AE 09094-0165 Germany Tel: +49-6371-47-6668 Fax:+ 49-6371-47-6662 E mail: usafe.sefp@ramstein.af.mil	**Gen. (ret.) James Jamerson** Vice President, International Programs, Lockheed Martin Washington Operations 1725 Jefferson Davis Highway Crystal Square 2, Suite 300 Arlington, VA 22202-4127 USA
Mr. Adam Kelly Geo-Marine BASH Project Manager 3160 Airport Road, Suite 22-A Panama City FL 32405 USA Tel: +904-871-5657 Fax: +904-871-4788 E mail: bashbam@aol.com	**Mr. Leslie Lemon** Lockheed Martin OR&SS 16416 Cogan Drive Independence, MO 64055 Tel: +816-373-9990 E mail: 102177.2336@compuserve.com
Dr. William Seegar Senior Research Scientist US Army, Edgewood Research, Development and Engineering Center County Aberdeen Proving Ground MD 21010 USA Tel: +1-410-436-2586 E mail: wsseeger@aol.com	**Mr. Harlan Shannon** Center for Conservation Research & Technology University of Maryland, Baltimore Room 105 TRC Building, 5200 Westland Blvd., Baltimore MD 21227 USA Tel: +410- 455-8047 E mail: shannonhd@aol.com
Lt. Col. Mark Smith Chief, Life Sciences/Human Systems European Office of Aerospace Research and Development 223/231 Old Marylebone Road London NW1 5TH UK Tel: +44-171-514-4285 Fax: +44-171-514-4960 E mail: msmith@eoard.af.mil	**Colonel Roger C. Craig** Vice Commander Headquarters Air Force Safety Center, United States Air Force 9700 G Avenue SE, Suite 240 Kirtland AFB NM 87117-5670 USA Tel: +1-505-846-2372 Fax: +1-505-853-0565 E amil: craigr@kafb.saia.af.mil

Tel-Aviv University

The International Center for the Study of Bird Migration at Latrun

S.P.N.I.

Flying with the Birds

Written by Dr. Yossi Leshem and Dr. Ofer Bahat

The book is in English, in a large format (24 cm X 34 cm), 264 pages with hundreds of excellent color photographs, graphs and sketches. The book was published by Yedioth Ahronoth and the Society for the Protection of Nature in Israel, July 1999.
The book can be purchased at the special price of $30 (standard price $40) per book including postage and handling by air mail.
This is a unique nature book that will carry you to new heights, soaring wing to wing with millions of migrating birds.
The book describes an innovative study, undertaken jointly by the Israel Air Force, Tel-Aviv University the Society for the Protection of Nature in Israel and the Ministry of Science. Hundreds of ground-based observers, light aircraft, a motorized glider, radar, and unmanned aircraft were used to follow migrating birds over Israel. This combination of research methods reduced bird-aircraft collisions in the Israel Air Force by 76%!
The book depicts the phenomenon of migration in the animal world, flight, and navigation principles in birds and the effect weather has on migration routes. It includes hundreds of fantastic color photographs taken by some of the best nature photographers in Israel and the world, some of which were taken from the motorized glider that followed the birds in the air. Readers will be enthralled by the amazing stories of fighter pilots whose aircraft was hit by birds forcing some to eject and unfortunately, killing others.
This book is a must for nature lovers and flight and plane aficionados as well. The authors are among the major ornithologists in Israel and have spent many years studying birds.

Dr. Yossi Leshem, the general director of the Society for the Protection of Nature in Israel (SPNI) until 1995, is now on the staff of Tel-Aviv University. He established and coordinated the SPNI's Israel Raptor Information Center for 11 years. He did his doctoral research on the migration routes of soaring birds over Israel, a cooperative venture with the Israel Air Force, and some of the results appear in this book. He is also the author of dozens of articles and books on these subjects. Dr. Leshem is now in the process of establishing the International Center for the Study of Bird Migration at Latrun in Israel, a center for research, education and nature conservation.

Dr. Ofer Bahat did his doctoral work at Tel-Aviv University on the ecology and physiology of vulture populations in Israel. He worked with Dr. Leshem for 10 years at the SPNI's Israel Raptor Information Center and coordinated the SPNI's Israel Ornithology Center between 1988 and 1991. He is also a gifted nature photographer and some of his work appears in this book.

"Flying with the birds" won the prestigious Maj. General Yitzhak Sadeh prize for military writing in 1994. The late Prime Minister Yitzhak Rabin and the commander of the Israel Air Force, Maj. General Eitan Ben-Eliahu were both present at the ceremony. This was the first time in the 23 years the prize existed that a book covering a biological subject won a prize for military writing.

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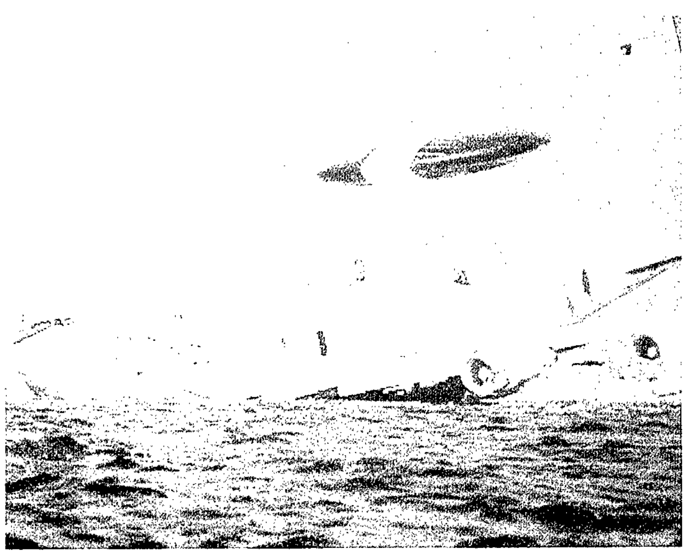
Introduction

Man's flight through life is sustained by the power of his knowledge

Above: The motorized glider used for migration research, escorts a flock of 2000 white pelicans from the Lebanese border south to the Egyptian border. The motorized glider flew wing tip to wing tip with the migrating birds 5-11 hours almost every day (Photo: Yossi Leshem).

Below left: 15/7/96, a Belgian Air Force C-130, collided with a flock of starlings at Eindhoven, The Netherlands. Thirty-five people were killed and six were badly injured

Below right: 14/7/96 (one day earlier!) a NATO Boeing E3A AWACS, collided with birds while taking off in Aktion, Greece. The aircraft was destroyed.



A white pelican taking off from the Hula Valley in the north of Israel to continue migrating. (Photo: Eyal Bartov)